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Water Resources Support Center
Institute for Water Resources

NATIONAL ECONOMIC DEVELOPMENT PROCEDURES MANUAL-

URBAN FLOOD DAMAGE

MARCH 1988

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The primary purpose of this report is to provide an expanded description of the Urban benefit evaluation procedures recommended in the Water Resources Council's Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies. The report presents specific procedures for the entire process of urban benefit estimation and is intended for use in project feasibility planning and evaluation. It is intended to be a reference guide to questions an analyst might have in conducting an urban benefit evaluation.

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NATIONAL ECONOMIC DEVELOPMENT PROCEDURES MANUAL
URBAN FLOOD DAMAGE

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PREFACE

This manual is part of a series of comprehensive guides to computing Nation Economic Development Benefits. Direction for this report came from working committee which consisted of Robert M. Daniel, the technical monitor, Robert L. Fulton of the Office of the Chief of Engineers; Nahor B. Johnson of North Atlantic Division; Howard N. Thelan of Omaha District; Frank R. Reynolds Jr. of Wilmington District; Carl O. Foley of the Board of Engineers for Rivers and Harbors; Larry M. Kilgo of the Lower Mississippi Valley Division; and, Michael R. Krouse, Joe Auburg, and Stuart A. Davis of the Institute for Water Resources; all of the Army Corps of Engineers, and, James Warren of the Bureau of Reclamation in Amarillo, Texas. Stuart Davis was the editor and principal author. Nahor B. Johnson contributed Chapter XI on discounting, and major sections on computing expected annual damages and the effect of economic changes on equivalent annual damages. William J. Hansen was the co-author of Chapter XI. James Warren contributed major portions on depth-damage functions, made numerous other suggestions, and provided references. Frank Reynolds contributed Chapter VIII on structural measures. Carl Foley contributed portions on report documentation and expected annual damages. The editor wishes to acknowledge the valuable review comments and suggestions by William Hansen and David L. Moser of the Institute for Water Resources, Carl Foley of the Board of Engineers for Rivers and Harbors, Nahor Johnson of North Atlantic Division, and Kirby B. Fowler and David Hottenstein, Jr. of the Office of the Chief of Engineers. Technical editing was done by Robert F. Norton of the Water Resources Support Center and Arlene Nurthen of the Institute for Water Resources.

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CHAPTER I

INTRODUCTION

PURPOSE

The purpose of this manual is to serve as a comprehensive guide for calculating National Economic Development (NED) benefits for urban flood damage reduction projects. This document presents specific procedures for the entire process of benefit estimation. It is intended to be a thorough reference guide to questions an analyst may have. As a practical guide, the manual gives greater emphasis on "how to do it" than "why do it", draws heavily from actual cases and incorporates numerous suggestions from report writers and reviewers in the Corps. The procedures found in this manual are not given as the only way regulations and guidance can be carried out. There are many "right" ways to perform the necessary analysis. Methods should be selected according to requirements of the type of project and planning document, local conditions and needs, availability of information, funding level to perform the study, and procedures that have been successful for the district in the past.

The fact that a particular procedure is not referred to in this document should not be construed as disapproval of that procedure.

This manual is based on the conceptual framework of the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P & G). It neither duplicates nor supercedes P & G, but rather elaborates and provides references for how the guidance of that document can be carried out.

INTENDED AUDIENCE

The manual is primarily designed for economists and planners concerned with economic analysis of Corps' projects. Planners, particularly project managers, must be able to understand and explain the process of benefit calculation. The planner can use this information to help determine which alternatives are promising enough to carry on to the later planning phases. The information in this document will give the planner the basis for selecting a recommended plan and determining its optimal size. It should be noted that the recommended plan is also subject to the local planner's desires and ability-to-pay, as well as, environmental, other social, and regional economic concerns. This report should also be useful to hydrologists, hydraulic engineers and anyone else involved in flood loss reduction. There are several steps in the evaluation process where hydrologists and economists must coordinate their work. For example, they are both directly concerned with future land use. The hydrologist's interest is in how future development may affect runoff patterns and subsequently raise flood levels, while the economist is concerned with how land use patterns affect estimates of future damages. They also must jointly determine the location of reaches and damage centers. It is in these areas that the manual will be most useful to hydrologists. This report should give all concerned an understanding of the multi-disciplinary approach that is necessary for good planning.

Recent initiatives toward increased partnership between the Corps and the non-Federal sponsors of water resource projects have included the policy of 50/50 cost-sharing of feasibility studies. This document will

familiarize non-Federal sponsors with the procedures traditionally used in the economic analysis of Corps' projects. Distribution to non-Federal sponsors is encouraged whether or not they intend to take an active part in the economic analysis.

NATIONAL ECONOMIC DEVELOPMENT (NED) BENEFITS

National Economic Development benefits are defined by P & G as increases in the economic value of the goods and services that result directly from a project. NED benefits are increases in National wealth, irrespective of where in the United States they may occur. NED costs are the opportunity costs of diverting resources from another source to implement the project and the uncompensated economic loss from detrimental project effects. A project is considered economically feasible if the NED benefits are higher than the NED costs. The benefit-cost ratio would then be greater than one.

The project with the highest net NED benefits (but not necessarily the highest benefit-cost ratio), which is otherwise engineeringly feasible, environmentally sound, and publicly acceptable is the NED plan. The NED plan is formulated in detail throughout the planning process and is given highest priority in selecting a recommended plan.

OTHER ACCOUNTS

ENVIRONMENTAL QUALITY

Environmental Quality (EQ) effects are very important to plan formulation. The National Environmental Policy Act of 1969 (NEPA), P.L. 91-90, requires that an environmental impact statement assess the significant changes in the environment that would result from an investment in Federal funds. EQ effects are assessed as to their magnitude, location, duration, reversibility, frequency, and the long term productivity of an area's value as a resource. The objectives of environmental evaluation are to affect the formulation of plans to avoid detrimental impacts, to take advantage of opportunities for enhancement and protection of resources, and to aid in determining a mitigation plan that will offset environmentally detrimental project effects. Guidelines to environmental quality evaluation can be found in Chapter Three of P & G; Engineering Regulation (ER) 1105-2-50, Environmental Resources, 29 January 1982; and Engineering Pamphlet (EP 1105-2-55), Environmental Resources, 5 February 1982.

REGIONAL ECONOMIC DEVELOPMENT

Regional Economic Development (RED) Benefits refer to economic gains from a project in a specific geographic area. These gains are measured by the net increases of income and employment. RED benefits include transfers or redistribution of wealth from other regions of the country as well as increases in National wealth incident to that specific region. While RED benefits cannot be used in determining the costs and benefits of

the NED plan, they can be extremely helpful to the local sponsor in assessing the value and financial feasibility of the project. A detailed description of the RED account can be found in Engineering Regulation 1105-2-30, pages A 11-12.

A complete evaluation of the regional economic development account should consider the net gain to regional income and employment. The value of economic activity that would not occur because of the project should be subtracted in the computation of net RED benefits.

OTHER SOCIAL EFFECTS

The Other Social Effects (OSE) account includes those impacts which are not incorporated in the other three accounts, but are still important enough to have a bearing on the decision-making process. OSE impacts are primarily impacts that can be quantified, but are not amenable to assignment of any monetary value. OSE includes changes in risks to life and health, community vitality, displacement, fiscal health, as well as the geographic and demographic distribution of income and employment impacts.

SCOPE

STATEMENT OF SCOPE

This manual is limited to discussion of procedures for estimating the national economic effects of flooding and computing NED benefits for all types of urban flood damage reduction projects. These projects may range from small, single-purpose flood control projects implemented under

a Section 205 Continuing Authority, to flood control as part of a major, multi-purpose project. The report covers all stages of the planning process, including the ten steps described in P & G for calculating urban flood damage reduction benefits, as contained in ER 1105-2-40. Also included is a discussion of some of the advantages and drawbacks of various benefit calculation methods. Emphasis is given to those aspects believed to be most troublesome. The procedures covered in this manual are applicable to reconnaisance reports, Continuing Authority detailed project studies, pre-authorization feasibility reports. The methodology used in preparing these reports will differ only in detail.

DESCRIPTION OF OTHER CHAPTERS

Chapter II. Chapter II gives a brief description of the basic theoretical principles on which benefit-cost analysis of water resource projects is based.

Chapter III. This chapter is an overview of the evaluation process. It explains how the use of, and procedures for, economic evaluation of projects differ by type of project and phase of the planning process. There is an explanation of how the ten steps in P & G correspond to the procedures found in this report. Most importantly, the role of economic analysis in the definition of problems and the formulation process is defined.

Chapter IV. Chapter IV is a discussion of the basic principles and procedures used in hydrologic and hydraulic engineering. It is intended only to serve as background so anyone with limited exposure to the

terminology will be able to understand the development of the basic relationships used in flood damage analysis.

Chapter V. This chapter is the first of three chapters that describe the process of defining the extent of flood damage problems in economic terms. It is critical that the person evaluating expected annual damages for any project be familiar with the types of physical and related damages that would occur with each class of property. Chapter V includes a description of the susceptibility of classes of property to physical and indirect flood losses. It illustrates the sequence of the evaluation process for defining existing conditions.

Chapter VI. Chapter VI describes the procedures for determining the future without-project conditions. Project benefits are based on a comparison of with-project conditions to the without-project condition of no additional flood control works, except those already under construction or where implementation is fairly certain. All other information gathered for the existing situation is updated to account for changes in land use economic activity and runoff patterns which lead to changes in the elevation-damage, elevation-frequency, and the damage-frequency relationships.

Chapter VII. Flood proofing, the administrative costs of flood insurance, modified use of residential property, evacuation, emergency costs, and business losses are the nonphysical costs of flooding. These additions to the physical costs of occupying the floodplain are described in Chapter VII.

Chapter VIII. The section on benefit calculation begins in Chapter VIII with a discussion of inundation reduction benefits. The usual

effects of both structural and nonstructural measures are noted. Procedures are described for calculating the residual damages and applicable benefits for each measure.

Chapter IX. Chapter IX describes the procedures for calculating the inundation reduction benefits of nonstructural damage reduction measures. These measures include flood warning-response, permanent flood proofing and permanent relocation.

Chapter X. Procedures are explained for determining enhancement benefits. Enhancement benefits include: 1) intensification in the use of business property when reduction of the flood threat allows for a more cost effective or more productive means of operation; and, 2) benefits from anticipated cost savings to businesses locating in the newly-protected flood plain, consistent with Executive Order 11988. Employment benefits, which come from utilization of unemployed labor in designated depressed areas, are described. Chapter X includes a discussion of negative benefits that result from project-induced flood damages. There is also a discussion of new and less frequently used benefit categories.

Chapter XI. Chapter XI demonstrates the use of discounting procedures for converting the estimated value of all future benefits to their present value. The effect of various discount rates and growth rates on equivalent annual benefits is shown.

Chapter XII. This chapter gives general guidelines on how much detail of the methodology, assumptions, input data, and calculations should be covered in project reports. This chapter is intended to aid in

determining what information is important to aid the reviewer in assessing the merits of the analysis and the alternative plans.

Appendix A. Appendix A describes the historical changes in Federal responsibility, laws, regulations, procedures, and agency programs. P&G and the Corps' procedures for analysis of projects are put in their administrative setting. The most important parameters that define the planning context under consideration are described. The economic basis for Federal involvement in flood damage reduction activities is described in this section.

Appendix B. Users of this manual are encouraged to continually find more reliable and efficient procedures for calculating benefits. Sources that may be useful in improving or developing new procedures identified in this manual and elsewhere should be pursued. This appendix contains annotated references to books and articles, data sources and computer programs to process them, and research reports describing the applicability of various measures.

Appendix C. Appendix C is a glossary of technical and administrative terms that appear in the course of planning and evaluating flood damage reduction projects.

CHAPTER II

PLANNING CONCEPTS

BASIS FOR FEDERAL INVOLVEMENT

Flood control is provided by the public sector because of the inability or failure of the private market to efficiently allocate this good. Market failure results from: 1) lack of sufficient information for the public to make rational decisions; 2) the inability of the market to provide the economies of scale or large capital outlays necessary for efficiently providing flood protection; 3) the inability of the market to exclude individuals from flood protection once it is provided, regardless of whether or not those individuals are willing to pay; and, 4) the external effects that flooding problems and their solutions can create. These four effects are discussed below:

PUBLIC INFORMATION

Information on flood hazards is not for sale or otherwise provided in the private market. Estimation of flood hazards requires years of record keeping, use of sophisticated modeling for calculation of rainfall, runoff, and stream flow probabilities, and the calculation of stream profiles for various probabilities of events.

ECONOMIES OF SCALE

The collection of information, the planning and design of projects, and the implementation of projects are usually most efficiently provided

on a large scale. Individuals cannot usually create detention areas or construct barriers of sufficient size to substantially reduce flooding problems. The most efficient allocation of resources usually requires collective action at a considerable scale. Federal involvement can provide further economies-of-scale in the creation and access to sophisticated programs and equipment, and the ability to make large-scale capital investment.

Flood control, like many other public goods, has a decreasing cost curve. Figure II-1 illustrates the optimal level of protection provided by a reservoir. Below a minimal scale, there is no economically feasible project. Flood protection can be provided until X^*, beyond which the marginal flood control benefits are exceeded by the marginal costs.

NON-EXCLUSION

Like other public goods, a primary characteristic of flood control is its "non-exclusivity." If flood control is provided to a community, it is often difficult or impossible to exclude individuals who are not willing to pay the cost of flood control services. For example, it is usually not possible to realign a levee design to leave out specific properties from the levee's protection. Similarly, reservoirs and channel enlargements reduce flood levels along miles of rivers and streams and owners of individual properties along the way cannot go unaffected, regardless of whether or not they are willing or able to pay for the project.

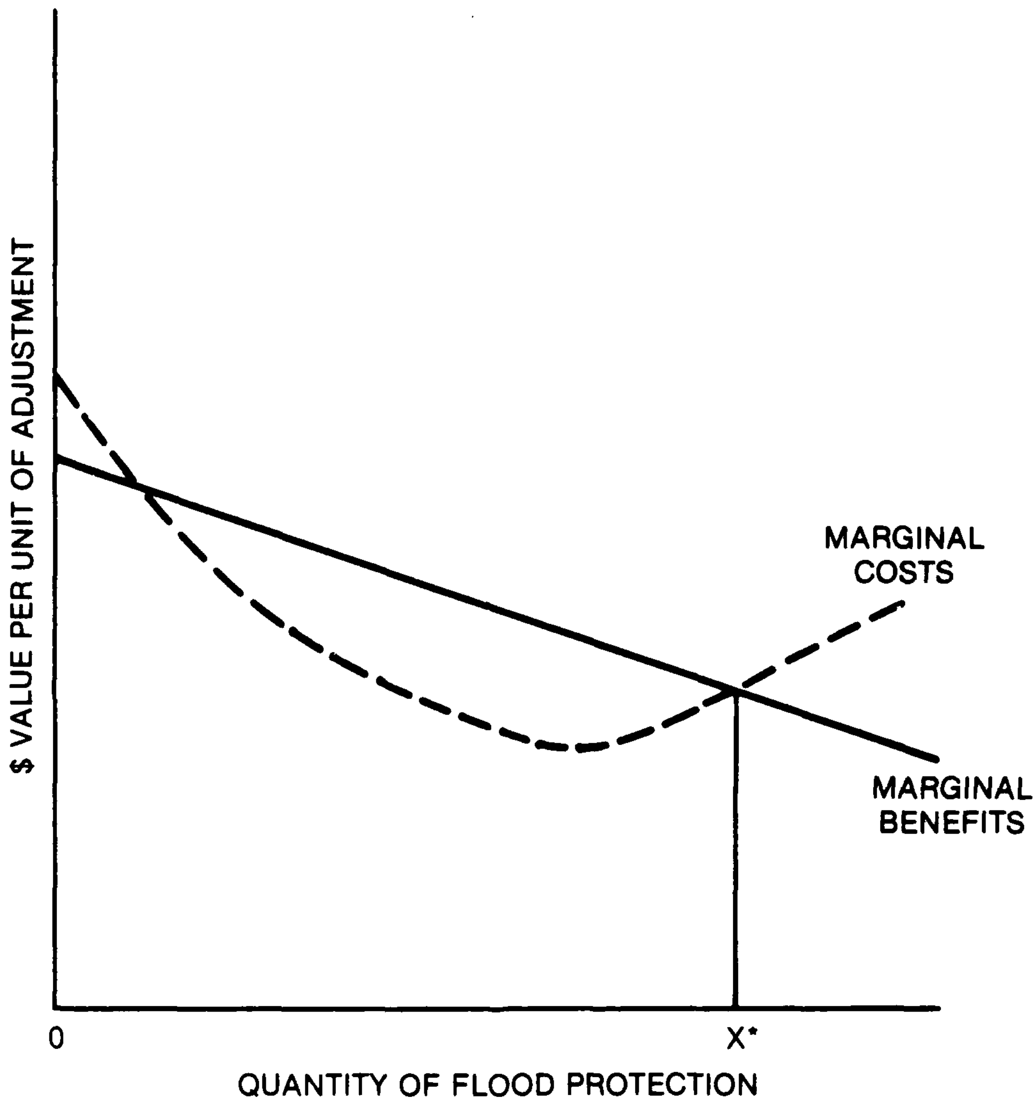


FIGURE II-1 ECONOMIES OF SCALE IN FLOOD PROTECTION

EXTERNALITIES

Externalities, whether good or bad, are uncompensated consequences to the utility of one party due to the actions of another party. Continual exposure to flood damage can lead to a persistent deterioration of property, which can have a detrimental effect on surrounding property. Flooding in developed areas can create an additional need for public services such as street and sewer repair that would be a liability to an entire community whether it is developed or not. Flood protection can reduce these external costs. Flood protection can also reduce the external costs of flooding from upstream development in and out of the floodplain.

Although flood protection measures will alleviate flood damage in protected areas, it can result in added risks or induced damages to downstream areas if flows are diverted or increased as a result of the project. Flood control projects can create environmental problems; however, government action can mitigate these impacts through proper design and offsetting measures.

Federal flood control activities can limit jurisdictional problems in dealing with multi-state basins to limit the actions a state may take at the expense of another.

THE FEDERAL OBJECTIVE

The Federal objective of Water Resources planning is to contribute to national economic development, consistent with protecting the Nation's environment. The 1936 Flood Control Act established the nationwide policy

that flood control on navigable waters and their tributaries is in the interest of the general public welfare and is, therefore, a proper activity of the Federal government in cooperation with the states and local entities. It provides that the Federal government may improve streams or participate in improvements for flood control purposes "if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected." Subsequent acts have enlarged the scope of the Federal interest to include consideration of all alternatives in controlling flood waters, by: 1) reducing the susceptibility of property to flood damage, and 2) relieving human and financial losses. The primary aspects of this activity -- called "floodplain management" -- are reduction of damaging floods and the susceptibility of property to flood damages. By controlling floodplain land use and development, floodplain management regulations seek to reduce future susceptibility to flood damages, consistent with the exposure involved, and, in many cases, help to preserve and protect natural floodplain values.

COST-BENEFIT ANALYSIS

The most widely used approach for evaluating the economic efficiency of a public works project is cost-benefit analysis. Cost-benefit analysis has three major purposes: 1) it can be used to help determine the most cost-effective composition and magnitude of an investment; 2) it can be used to determine if an investment is economically favorable; and, 3) it can be used to compare and choose between alternative investments. A fourth and less common use of cost-benefit analysis is to help determine

the timing of investments. The final decision for a public investment in a democratic society is based on political considerations. Cost-benefit analysis is only a tool to help with that decision. There are other social welfare criteria that need to be applied to investment decisions. P&G requires that thorough investigation and documentation be made of environmental quality impacts, regional economic development, and other social effects. If decision-makers believe that any of these other considerations are overriding concerns, they can recommend a project other than the one with the highest economic efficiency, including projects where the benefit-cost ratio is less than 1 to 1.

BASIS FOR PROJECT SELECTION

In evaluating the flood control projects that are undertaken, the water resource agencies follow four principles:

1. Willingness-to-pay. Willingness-to-pay is considered the standard for all NED benefits. Goods and services that are provided by a project have value only to the extent that there is demand by the consumer. Goods generated by the public sector are provided on the basis of an estimated willingness-to-pay since there is no private market to establish a price. In the case of flood damage reduction, an ex-ante (or pre-implementation) estimate is required of the total value that consumers would be willing to pay to avoid the damages and indirect costs of flooding. As an indicator of willingness-to-pay, estimates are made of physical damages that would result from flooding. For example, under existing conditions, estimates are made of the value of direct and indirect effects of flooding. These estimates are used to measure

consumer willingness-to-pay and also as a basis for determining project feasibility.

Estimates of physical damages that would occur from several frequencies of flooding; i.e. floods of various magnitudes, such as floods with 50%, 10%, 2%, 1%, or .2% annual chance of occurrence, can represent the major portion of willingness to pay for flood loss reduction. These estimates are used to compute the average annual damages as shown in Chapter Five. Assuming that a rational individual would be willing-to-pay at least the amount equal to restoring the damaged property to pre-flood condition, this value, plus a cost equal to time spent preventing damages, the cost of clean-up, evacuation, and irretrievably lost for production of goods and the delivery of services, becomes an estimated level of willingness-to-pay. Other factors that can contribute to willingness-to-pay include a risk premium for individuals who are averse to risks, inconvenience, and costs of trauma.

Aggregate willingness-to-pay for flood prone property is the total area under the demand curve (D-D) as illustrated in Figure II-2. P_1 indicates the total costs of rent and expected flood loss to occupants of a specific floodplain without flood control. Q_1 represents the portion of the floodplain demanded for urban development without flood protection. Area A is the consumer surplus, which represents the value of the developed floodplain over-and-above what floodplain occupants are willing to pay. A flood control project reduces the total costs of rent and expected flood loss to P_2. The total willingness-to-pay becomes the area under the demand curve between the origin and Q_2. This increases the portion of land for development from Q_1 to Q_2. The consumer surplus

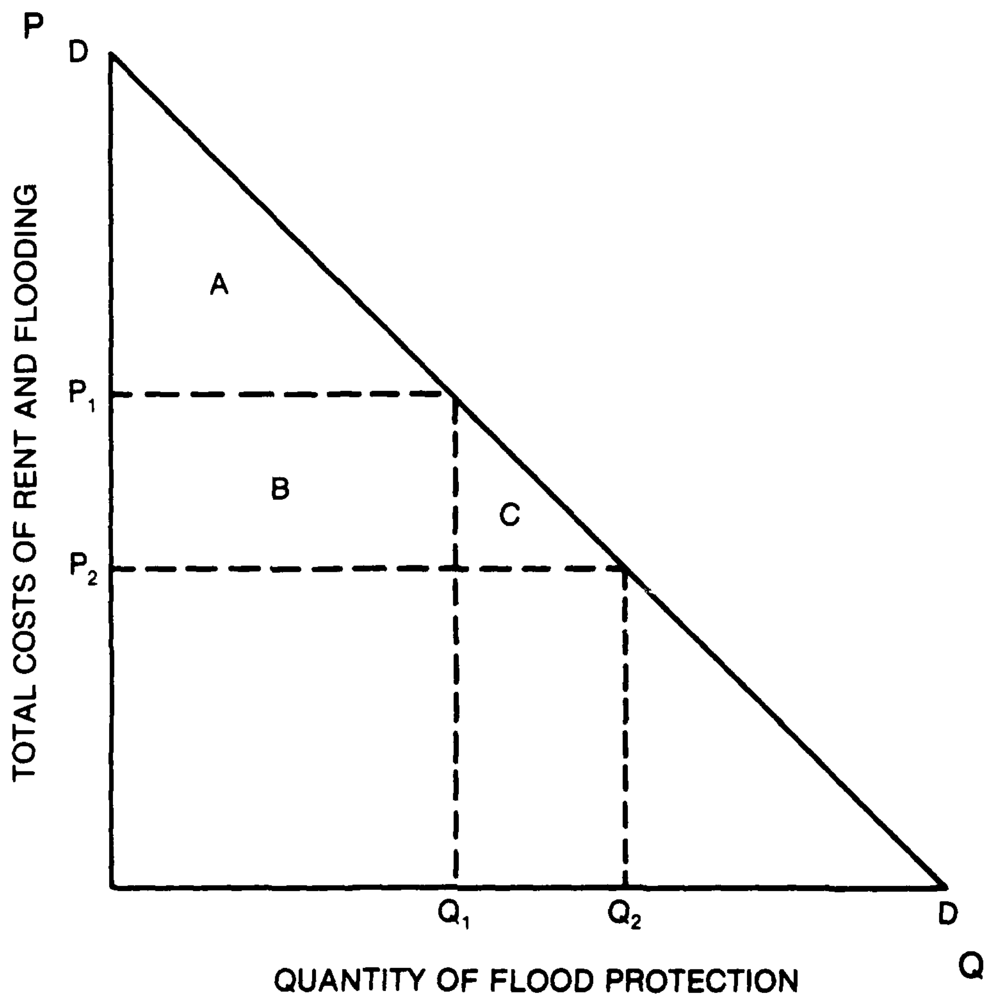


FIGURE II-2 WILLINGNESS TO PAY FOR FLOOD PROTECTION

increases from A to the total of Areas A, B, and C. Area B represents the inundation reduction benefit for reduction of flood loss to existing development. Area C represents the location benefit for newly developed land.

2. Maximum Net Benefits. The most efficient use of resources for any one project comes when benefits exceed costs by the maximum amount. The maximum net benefits concept is, therefore, the best measure of investment because it contributes the highest dollar value of increased output to the economy. The distinction between maximum net benefits and the highest ratio of benefits to costs is shown below in Table II-1 and in Figure II-3. In Table II-1, Plan A has the maximum benefit-cost ratio and Plan B has the maximum net benefits.

TABLE II-1

NET BENEFITS AND BENEFIT-COST RATIO COMPARISON

	Plan A	Plan B (NED Plan)
Average Annual Benefits	$660,000	$805,000
Average Annual Costs	$320,000	$425,000
Net Benefits (B-C)	$340,000	$380,000
Benefit-Cost Ratio (B/C)	2.06	1.89

It is clear that there is an economic gain for going beyond the scale of the project with the maximum benefit-cost ratio, as marginal benefits continue to exceed marginal costs.

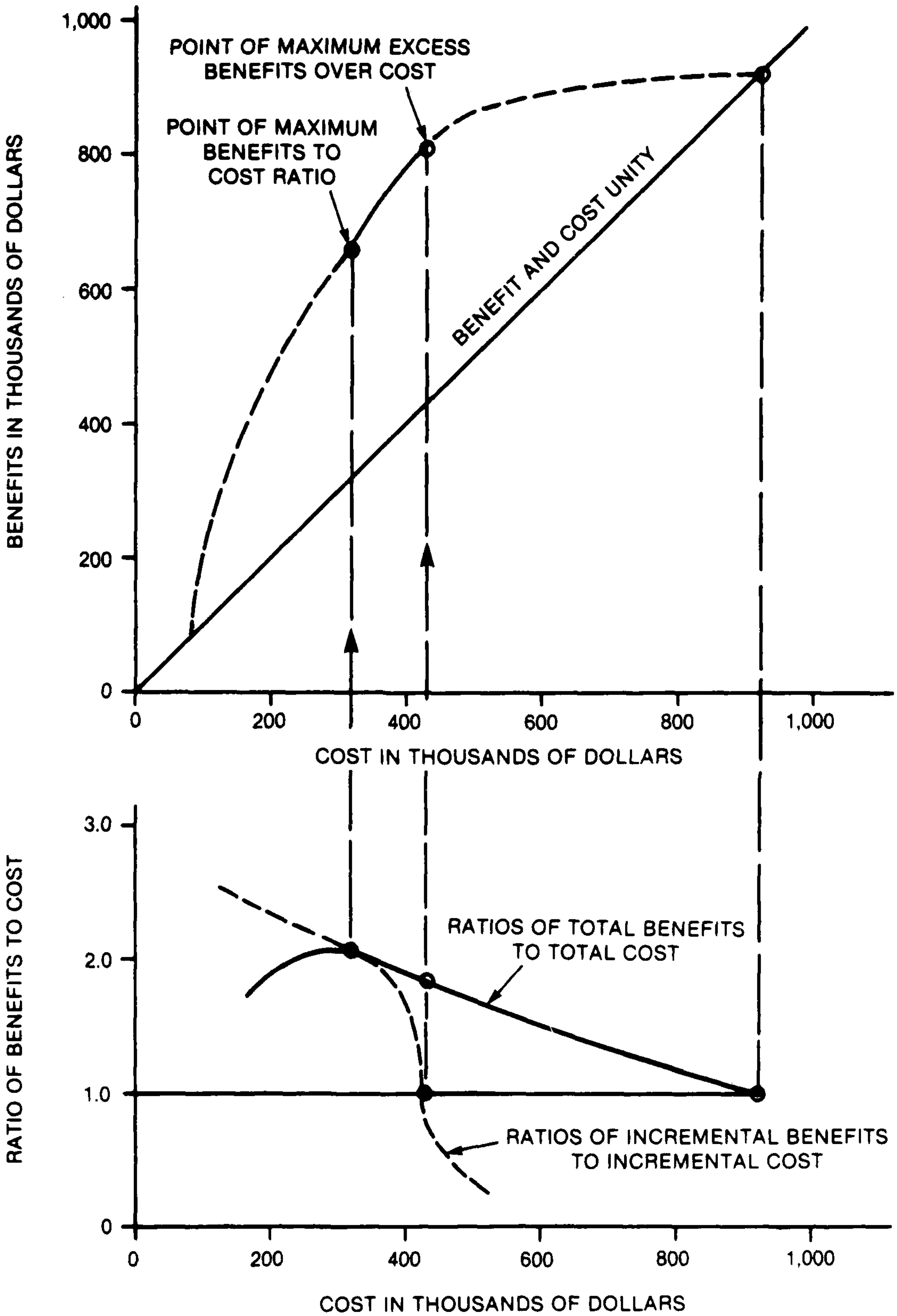


FIGURE II-3 MAXIMIZATION OF NET BENEFITS

3. Separable Justification. Each separable component should have a benefit-cost ratio of at least 1 to 1. A separable component is an element of the project that can be left out without disturbing the technical feasibility of the project. A separable component would also have to be technically able to function on its own. The separable justification criteria is a corollary to the maximum net benefit rule. A separable component with an unfavorable benefit-cost ratio would reduce the overall net benefits of the project.

4. Basis for Project Selection. In comparing economically efficient projects, a full accounting should be made of those effects which cannot be measured in monetary terms. It is also important, when considering the implementation of a number of projects, to realize that the implementation of earlier projects could affect the efficiency of later projects being considered for implementation. An example of this is when provision of a reservoir project lowers downstream flood profiles, thereby reducing the benefits of future downstream flood control projects.

PRINCIPAL FLOOD ALLEVIATION BENEFIT CATEGORIES

This section defines the categories of benefits attributed to flood damage reduction measures. The procedures for calculating these benefits are found in Chapters Eight, Nine, and Ten. As mentioned earlier, only NED benefits are discussed in this report.

INUNDATION REDUCTION BENEFITS

Most benefits from flood damage reduction projects come from the reduction of inundation damages. Inundation reduction benefits include reduction of both physical and nonphysical costs. These benefits include the saving of structure and contents from flood damage, the savings from alleviation of cleanup costs, production losses, the cost of flood fighting, evacuation, and traffic rerouting. Physical damages can be computed by application of depth-damage functions, which include application of generalized curves, project-specific curves, or site-specific relationships. They can also be estimated from field surveys. Average annual damages can then be computed from defining stage-damage, stage-discharge and discharge-frequency relationships. Development of these relationships and computation of annual damages are illustrated in Chapter Six. Calculation of inundation reduction benefits is illustrated in Chapters Eight and Nine.

Inundation reduction benefits result from alleviation of the following effects:

PHYSICAL DAMAGE

These include structural damages to buildings; loss of contents of the building, including furnishings and equipment; decorations; raw materials; materials used in processing; processed material; and, damage to streets, highways, railways, sewers, bridges, power lines and other infrastructure. Physical damages are evaluated separately for residential, commercial, industrial, and public properties; and for utilities, vehicles and roads. The alleviation of physical damages usually accounts for the largest share of flood mitigation benefits.

NON-PHYSICAL DAMAGE

1. Income Loss. Income loss is the loss of wages or net profits to businesses over and above physical flood damages. It results from a disruption of normal activities that cannot be recouped from other businesses or from the same business at another time. Prevention of income loss can be counted as a national benefit only to the extent that such loss cannot be offset by postponement of an activity or transfer of the activity to other establishments.

2. Emergency Costs. Emergency costs include those expenses that result from a flood and not from just the risk of flooding. Emergency costs include expenses for emergency evacuation, flood fighting, administrative costs of disaster relief, public clean-up costs, and increased costs of police, fire and military patrol. Emergency costs should be determined by specific survey or research and should not be estimated by application of arbitrary percentages of physical damage estimates. Frequently, data are only available for one significant flood. Applying the same loss to other floods based on the same loss for number of properties affected is usually an adequate approach.

3. Temporary Relocation. Temporary evacuation costs include temporary lodging and the additional costs of food and transportation due to forced evacuation for extended periods of time. Often this is included in emergency costs.

4. Other Costs of Occupying the Floodplain. Other floodplain occupance costs include: a) floodproofing costs incurred in construction of new development; b) the administrative costs of flood insurance; and, c) modifying the use of floodplain property because of the flood threat.

LOCATION BENEFITS

Location benefits result from new, more profitable activities locating in the floodplain because of a project reducing the expected value of flood losses. Benefits are the increase in net income of the activities over the alternative site, less the net income lost to any displaced activity

INTENSIFICATION BENEFITS

Intensification benefits occur when, because of flood protection, a business finds it profitable to modify its operations at its present floodplain location, and that modification results in an increase in net income to the business. The modified investment may involve an increased investment, such as additional or more highly skilled labor, new equipment, increased hours of operation, or the production of a more highly valued product. The benefit is the increased net income due to the modified operation, minus any additional residual flood loss which might be caused by the change in method of operation.

EMPLOYMENT BENEFITS

Employment benefits are NED benefits that result from the use of otherwise unemployed or underemployed labor for project construction. Employment benefits apply to flood control and other water resource project construction in qualifying communities as designated in the "Fiscal Year Reference Handbook", published annually as an Engineering Circular (EC).

The labor costs of implementing a flood damage reduction project generally represent an opportunity loss to society as the provision of other goods and services are foregone. In the case where the same labor type is unemployed, and the area where the project is to be implemented is in a state of chronic economic depression, there is no opportunity loss or goods and services foregone. When this is the case, labor cost can be used in benefit-cost analysis as employment benefits. These benefits result from employing otherwise unemployed labor.

Since employment benefits are not specific to Flood Damage reduction, there will be no further discussion of them in this manual. Further information on the applicability and the procedures for computing employment benefits can be found in Report of Survey of Corps of Engineers Construction Work Force, Institute for Water Resources Research Report 81-R05, (Dunning, C. Mark, Fort Belvoir, Va.: U.S. Army Corps of Engineers, Institute for Water Resources, 1981).

OTHER INTEGRAL PLANNING AND EVALUATION CONCEPTS

WITH-AND WITHOUT-PROJECT CONDITION

All public works investment must be evaluated for with- and without-project conditions over the planning horizon, or estimated project life. The purpose of making a distinction between with- and without-conditions is to isolate the changes that are expected to occur as a result of a project, from changes that would occur if the project were not undertaken.

The without-project condition is an assessment of the flood problem, assuming no action is taken by the Corps to alleviate it. If flood control works or any other significant action is imminent without Corps' action, those actions should be considered part of, and help to define the without- project conditions. Imminent actions would include funded flood control measures, development under construction, or development limitations under the National Flood Insurance Program, Executive Order 11988, and any local regulations in effect.

Existing activity can be expected to remain in place, unless it is in deteriorated condition or abandoned. Structural assessments should be made of existing flood control works to determine the realistic degree of protection.

Any changes in population, land use, affluence, or intensity of use expected as a result of the project, should be considered in the definition of with-project conditions.

PERIOD OF ANALYSIS

ER 1105-2-40 (Appendix A) defines period of analysis as the time required for implementation plus the time in which significant benefits or adverse impacts will be realized. The period after implementation cannot exceed 100 years. Most Corps reports use a period of 50 or 100 years after implementation. For planning purposes, the period of analysis should be the same for all alternative plans being considered for a specific study. Planning conditions such as population, land use, and storm water runoff are usually held constant for the period between 50 and 100 years after implementation. Projections are not generally made beyond 50 years

because of the uncertainty in forecasting further into the future. There is no specific criterion for selecting the period of analysis.

DEGREE OF PROTECTION

The degree of protection is the criterion used to express the flood damage prevention effectiveness of a project, i.e., damages are eliminated up to this level. Generally, it is the flood level at which residual adverse effects are considered relatively minor. In areas where there is no indication that floods exceeding the level of protection would cause a catastrophe, the NED plan should generally be recommended.

Design frequency terminology used in flood damage reduction is defined in the following four paragraphs:

1. Probable Maximum Flood (PMF). This is the most severe flood which can result from the most critical combination of precipitation (and snow melt), minimum infiltration losses, and concentration of runoff at a specific location, that is considered "reasonably possible" from a particular drainage area, based on scientific meteorological and hydrologic engineering analyses. The PMF is used as the spillway design flood for large dams to insure their safety against even a remote possibility of failure.

2. The Standard Project Flood (SPF). This represents the flood runoff that may be expected from the most critical combination of precipitation (and snow melt), minimum infiltration losses, and concentration of the runoff at a specific location, that is considered "reasonably characteristic" of the region and drainage area involved, excluding extraordinarily rare combinations.

3. Design Flood. This is a flood adopted for the design of individual flood control works. It provides technically feasible protection which normally is economically justified. The design flood may be less than the standard project flood, depending upon the residual flood hazard to life and other considerations -- including social and environmental objectives.

4. One Percent Flood. The one percent flood, also known as the 100-yr flood, is a flood with a one percent chance of being exceeded in any given year. It is particularly important because it is the degree of protection below which building regulations of the National Flood Insurance Program and provisions of Executive Order 11988 apply.

RISK AND UNCERTAINTY

The measurements, estimations, and projections that planners make and use in calculating project benefits are always subject to varying degrees of potential inaccuracy. This potential inaccuracy can be classified as risk or uncertainty.

Risk is where a potential outcome can be predicted with known probability. Risk can be most accurately defined when there are stable conditions and a long history of information exists on which to make a prediction. Uncertainty is where conditions are too unstable, or not enough history exists, to make a prediction with a high degree of confidence. Despite this distinction, there is usually little difference between the ways risk and uncertainty are managed.

Plans should be examined to determine the degree of risk and uncertainty inherent in the data. The importance of analyzing risk and

uncertainty is that it gives the decision-makers a knowledge of reliability of the data on which the benefit-cost analysis and the study's recommendations are based. The following are some alternative ways in which risk and uncertainty can be analyzed and displayed, and used to affect plan formulation, evaluation, and review (commensurate with type of study and resources available):

1. Collect more detailed data.
2. Use more refined analytic techniques.
3. Select measurements with better known performance characteristics.
4. Risk and Uncertainty can be analyzed and displayed for use by decision-makers by performing a sensitivity analysis of the estimated benefits and costs of alternative plans, using factors significant to project justification. This will allow plans to be evaluated based on a limited number of reasonable alternative conditions.

The potential negative implications of risks and uncertainty can also be diminished by increasing the safety factor in project design and by reducing irreversible or irretrievable commitment of resources.

CHAPTER III

OVERVIEW OF THE PLANNING AND EVALUATION PROCESS

TYPES OF STUDIES

The guidance given in the P & G, and, consequently, in this manual, is relevant to Section 205 Continuing Authority Reports; detailed project pre-authorization feasibility reports, Section 216 studies for changes to completed studies, and post-authorization reevaluation reports. This chapter provides general information on each of these types of reports and also describes the stages of planning that are relevant to each type. Additional guidance on feasibility and pre-construction planning studies can be found in ER 1105-2-10, Feasibility and Preconstruction Planning and Engineering Studies, 18 December 1985.

The NED evaluation process for Section 205 continuing authorities and pre-authorization studies is roughly the same. Only the level of detail changes. The feasibility of a Corps' project, no matter what the size, is investigated in the two-phased planning process described below:

TWO-PHASED PLANNING PROCESS

The 1986 Water Resource Development Act (Public Law 99-662) institutionalized 50-50 cost-sharing for feasibility studies. Title I of the Act states that 50 percent of the costs for feasibility studies be contributed by the state or local sponsor of the project, and no more than half of that amount may come from the provision of in-kind services. The

process allows that the feasibility study be preceded by a reconnaissance phase, which will:

1) define the problems, opportunities, and potential solutions;

2) determine the potential for a project based on the benefits, costs, environmental impacts, and the extent of Federal interest;

3) estimate the costs of the feasibility phase; and,

4) identify the extent of local interest and support for the potential solutions. This first phase is entirely Federally-funded. It is limited in time and resources. If there is adequate justification and interest, the process continues to the feasibility phase described below under discussion of the six stages of the planning process.

SECTION 205 CONTINUING AUTHORITY REPORTS

Continuing Authorities are small projects authorized under Section 205 of the 1948 Flood Control Act. Continuing Authority studies only require approval by the Corps' Division office and the Office of the Assistant Secretary of the Army for Civil Works. The Federal cost of a 205 project cannot presently exceed $5,000,000. This limit was set by the Water Resource Development Act of 1986, P.L. 99-662. Therefore, the planning activity for this type of study is necessarily limited. Continuing Authorities generally have localized implications, and so the study area is limited. Flood damage assessment should cover every property or community service that is subject to flood damage. However, the limited budget for a Continuing Authority may create the need for sampling rather than inventory, and application of generalized damage functions.

1. Reconnaissance Report. The most detailed planning for Continuing Authorities is in the reconnaissance phase. The purpose of the reconnaissance report is to recommend for or against further study. Primary data gathering in this phase is generally limited to industrial property, large commercial establishments, public and institutional property, and a sampling of small commercial and residential establishments. Sampling procedures and other means to handle planning budget constraints will be discussed in Chapter V and Appendix A.

2. Detailed Project Report. Continuing Authority projects that clear the reconnaissance phase advance to the design phase for preparation of the detailed project report. Work in this phase covers detailed design and an updating of costs and benefits from the material collected in the reconnaissance phase. While other parts of the Continuing Authority planning process are entirely Federally funded, this phase is funded on a 50-50 cost-sharing basis with local governments.

A favorable Detailed Project Report is generally followed by development of detailed plans and specifications, which ordinarily require no detailed economic analysis, unless there have been significant changes in the design.

PRE-AUTHORIZATION REPORTS

1. Reconnaissance Report. Just as with the Continuing Authority, the purpose of the pre-authorization reconnaissance report is to recommend for or against detailed planning. As with the reconnaissance phase of the Continuing Authority the purpose is to determine whether there is any feasible project and to plan the work for the feasibility phase.

2. Feasibility Report. The detailed planning for large pre-authorization projects is done when preparing the feasibility report. The feasibility report requires study authorization, either through a basin-wide or project-specific analysis. It is only after detailed planning, where a project has been proven to be publicly acceptable, economically feasible, environmentally sound, and has a local sponsor, that a project becomes eligible for authorization. Feasibility reports require detailed study of primary economic, engineering, and environmental data. On rare occasion, interim survey reports may be submitted in response to Congressional inquiry, but submittal of a full report is still required for project authorization. Phases of the feasibility report process are described below in the section under plan formulation.

SECTION 216, CHANGES TO COMPLETED PROJECTS

Section 216 reports are authorized under Section 216 of the River and Harbor and Flood Control Act of 1970. Procedures for Section 216 studies are essentially the same as pre-authorization feasibility reports. However, funds are more limited, analysis is specific to particular components of the project, and, if possible, extensive use is made of existing data.

POST-AUTHORIZATION REEVALUATION REPORTS

Once a flood alleviation project has been Congressionally authorized, the details of the recommended project can still be changed in size, types of measures used, and somewhat in the geographic area covered by the project. In this detailed design phase, it is still necessary to

demonstrate the economic efficiency of the recommended plan. This would be done in a reevaluation report. While this phase is primarily limited to the detailed design of the project, economic analysis should be updated for any changes in the project design, relative prices for various components of the project costs, and any major change of economic activity in the study area.

PLAN FORMULATION AND EVALUATION PROCESS

ROLE OF NED CONSIDERATIONS IN PLAN FORMULATION

The maximization of net economic returns has long been the primary objective in the formulation of Federal water resource programs. Alternatives are formulated to achieve the highest net return on investment. Formulation of alternatives should recognize both existing and future economic conditions. This means that not only changes in the physical system as they affect drainage patterns and stage-frequency relationships should be considered, but also changes in economic components, such as land use and intensity of economic activity. This section is included to illustrate the role economic analysis has to play in each stage of the planning process.

To summarize from earlier discussion, the decision rule for the selection of the components and scale of Federal water resource development is to maximize net benefits--the difference between gross economic benefits and gross economic costs. In determining the project scale, additional increments will be added to the project as long as the value of each new increment exceeds the marginal costs. Increments will

still be added even as the project benefit-cost ratio falls, as long as net benefits continue to increase.

If the benefits and costs of each alternative can be expressed in monetary terms and if there is no overriding constraint, such as lack of public support or severe environmental impacts, the process of project selection is very straight-forward. The major problem occurs with the consideration of "intangible" factors. Any factor that cannot be expressed in monetary terms should be quantified, if possible, using another standard. For example, impacts could be expressed in terms of number of people, number of properties, or acres of land affected. If not, the effects should at least be described. The extent to which the selected plan differs from the plan with the maximum net tangible benefits should be noted, along with the reasons for the deviation from the NED plan.

STAGES OF PLANNING

The planning process can be broken down into six stages: 1) identification of problems, needs, opportunities and objectives; 2) establishing the base condition; 3) forecasts of future conditions; 4) formulation of alternatives; 5) evaluating their effects; and, 6) comparing the plans and making a recommendation. Each of these steps is described below:

1. Identification of Problems, Needs, Opportunities, and Objectives. The first step in any study is to document the history of flooding problems, including the implications for physical development and the economic and social well being of the area. The work includes the

compilation of historical records -- such as reports and newspaper accounts -- to determine the extent of the flooding problem; meeting with community officials, staff, and the public to determine concerns and plans for the area; and, a study of the resources and economic base to determine the opportunities. The problems and opportunities identified in this phase may change as the planning process continues. Through this effort, specific objectives of the study are determined and defined as the planning process continues.

2. Establishment of the Existing Conditions. Once beyond the reconnaissance level investigation of problems, opportunities, and initial setting of objectives, the second stage begins the detailed level of planning. Existing conditions and resources are inventoried and evaluated on a site-specific basis. Average annual flood damages are estimated after a thorough inventory of properties and analysis of the historical records and synthetic modeling of existing rainfall, drainage, and streamflow patterns. Consideration is given to the effect of existing flood protection structures and structures that would be in place in the time a project can be implemented. The procedures for economic analysis in Stages 1 and 2 are described in detail in Chapter V of this manual.

3. Forecast of Future Conditions. Planning studies should consider the effects of future changes in population, land use, level of economic activities, and drainage structures, and must determine the effects of these changes on the expected flood damage for every reach of the study area. This requires coordination with state and local agencies that have their own projections and land use plans, the use of Federal statistics and projections of population and economic activity, and the Corps' own

assessment of probable future conditions. The same modeling techniques that were used to determine the physical extent of existing flood problems and average annual damages should still be used. The procedures for evaluating future flood damages are described in Chapter VI.

4. Formulation of Alternative Plans. All reasonable alternatives should be considered in the formulation of plans. Economic analysis, public participation, and environmental considerations are all important in screening alternatives to determine which plans should be carried through in detail. Nonstructural alternatives should also be given detailed consideration for solving the flood problem.

5. Evaluation of Effects. Formulation of alternatives, described above, is a continual process. Plans become defined in detail as national economic, regional economic, social and environmental factors are evaluated. During Stage 5 of the planning process all project impacts are evaluated with emphasis on the NED benefits for each plan. These benefits are expressed in constant dollars, discounted to the base year and annualized over the period of analysis. Benefit-cost ratios and net benefits are calculated. Procedures for calculating NED benefits are described in Chapters VIII through XI. All significant expected effects should be quantified, where possible. All other effects should be displayed and described. The NED plan, the plan that maximizes the differences between benefits and costs, subject to constraints of public and environmental acceptability, should be examined in detail throughout the planning process.

6. Comparison of Alternatives and Recommendation of a Plan. The final stage of the planning process comes when all plans, given serious

consideration and studied in detail, are compared for the selection and refinement of the recommended plan. During this stage, the best compatible elements of plans can be combined to produce a plan that maximizes economic efficiency and other social welfare considerations. It is well to remember that independent elements of a plan must always be incrementally feasible.

STAGES OF BENEFIT CALCULATION

With its focus on benefit calculation, this manual is concerned with planning stages one, two, three, and five. The manual describes the concerns of benefit calculation in a chronological order, which includes analysis of: 1) existing conditions without-project; 2) future conditions without-project; and, 3) computation of benefits. The procedures in this manual cover the same ten steps found in Chapter 2, Section 4 of P & G. Figure III-1 illustrates the ten steps found P & G for calculation of urban flood damage reduction benefits. Table III-1 shows how the ten steps in P & G compare with the organization of this manual.

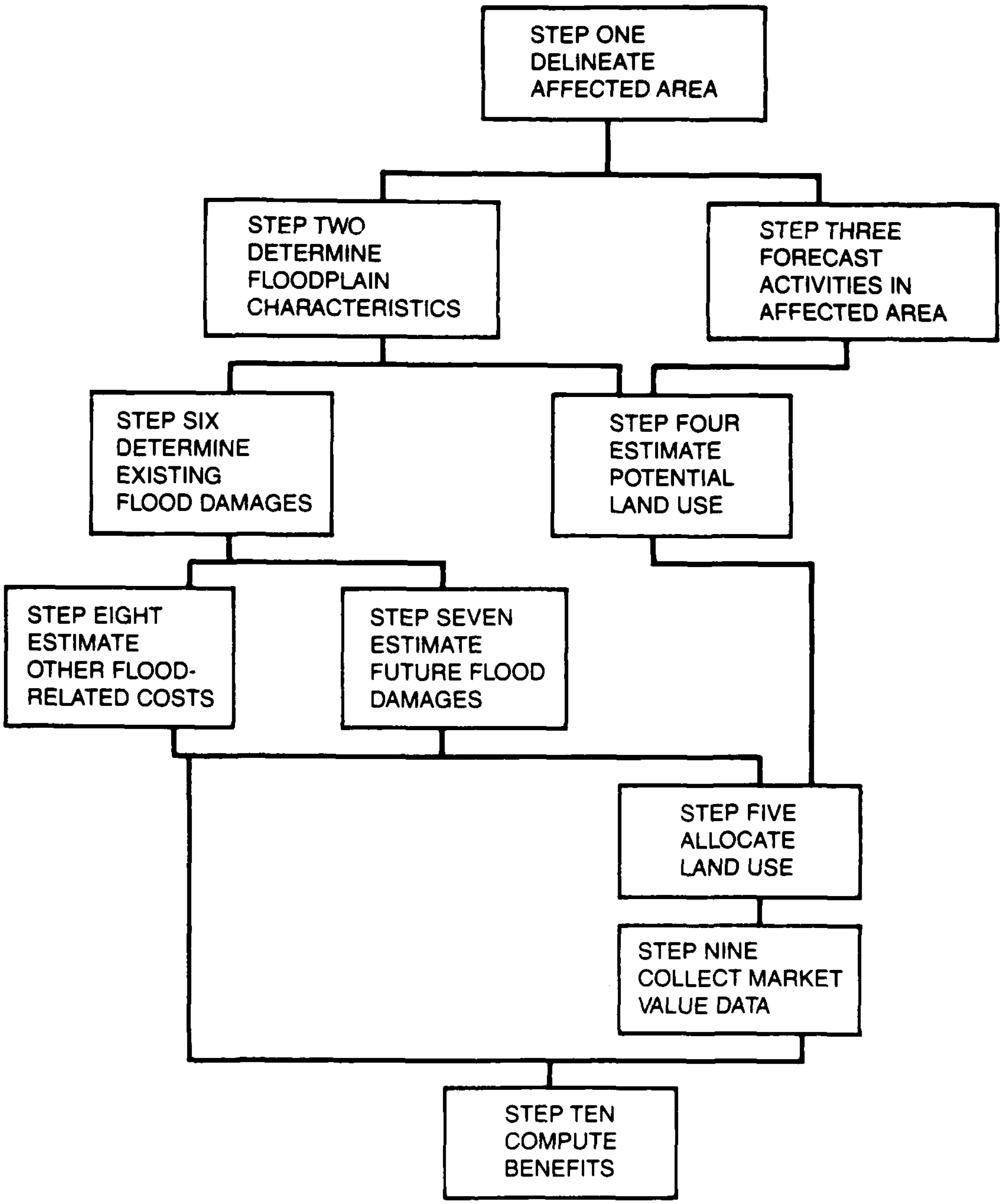


FIGURE III-1 PRINCIPALS AND GUIDELINES FLOWCHART OF URBAN FLOOD DAMAGE BENEFIT EVALUATION PROCEDURES

Table III-1

COMPARISON OF THIS MANUAL'S CHRONOLOGY AND P & G'S 10 STEPS TO CALCULATE FLOOD DAMAGE REDUCTION BENEFITS

Existing Conditions; Without-Project (Chapters V and VII)

- Delineate Affected Area (P & G Step 1)
- Determine Floodplain Characteristics (Step 2)
- Determine Existing Flood Damages (Step 6)
- Determine Other Costs Of Using The Floodplain (Step 8)

Future Conditions: Without-Project (Chapters VI and VII)

- Project Activities in the Affected Area (Step 3)
- Estimate Potential Land Uses (Step 4)
- Project Land Uses (Step 5)
- Project Future Flood Damages (Step 7)
- Determine Other Costs of Using the Floodplain (Step 8)

Compute Project Benefits (Chapters VIII through XI)

- Repeat Steps 3 Through 8
- Collect Land Market Value and Related Data (Step 9)
- Compute NED Benefits (Step 10)

CHAPTER IV

HYDROLOGIC AND HYDRAULIC PRINCIPLES

This chapter describes the principles important to hydrologists and hydraulic engineers in determining basic flood loss reduction studies. More specifically this information is intended to serve as an introduction to the procedures for calculation and use of elevation-frequency relationships, described in the next chapter. It is hoped that this information can help economists, planners, hydrologists and hydraulic engineers to more clearly communicate their own requirements and to better understand the outputs of, and the need for, each other's work. Close cooperation between the disciplines is important to an efficient study. Efficiencies can occur in data collection efforts, such as combining requests for survey information and agreement of what flood reaches to use as the primary unit of analysis. Hydrologic Engineering in Planning, by Burnham, Johnson, and Davis, (Davis, Ca.: U.S. Army Corps of Engineers Hydrologic Engineering Center, 1981) is highly recommended for those wanting more detailed information on this subject.

The elevation-frequency (stage-frequency) relationship is the primary product of hydrologists and hydraulic engineers that is used in economic analysis. The elevation-frequency relationship indicates the elevation water can be expected to reach at a given location for a continuous range of flood probabilities. Flood velocities and durations are important and can also be obtained from the hydrologic and hydraulic analysis.

GENERAL DEFINITIONS

Drainage basin. A drainage basin is the entire area from which a river or stream collects its water. Drainage basins are defined by ridges, hills, mountains, or any rise in topography that separates the flow of water from one area to another.

Basin characteristics. Basin characteristics are defined at the outset of a study by historical records of flows, volumes, duration, and the amount and distribution of rainfall. Other important variables are the size and shape of the watershed, the length of the main channel and important tributaries, land and channel topography, density of the drainage pattern, and the extent of natural and man-made storage.

Flood characteristics. The variety of floods can be seen as a spectrum with one extreme represented by the Lower Mississippi, which is characterized by slow rise, long duration events, covering very wide floodplains. There can be as much as two weeks of lead time, with increases being indicated by amount of precipitation, river levels, reservoir levels, and anticipated snow melt. Large river and tributary flooding cause backwater flooding into sub-basins that would otherwise be unaffected by heavy flooding. The other extreme is a very quick rise, high velocity flooding, which is common in the West and other areas where there are large changes in elevation over short distances. This type of flooding may be particularly threatening to public safety. Flash flooding, which is defined by the National Weather Service as any flood where there is less than six hours lead time from detection to inundation, can occur on any small stream, particularly where there is a great change

in elevation. Additional factors include the speed of onset, velocity, duration, sediment and debris load. These factors may greatly influence the extent of damage for each level of flooding.

Sources of Flooding. The flood characteristics described above depend largely on the source of flooding. Causes of inland flooding include ice jams--which occur throughout much of the Northern United States and log jams and sediment can clog streams. Serious problems can arise from inadequate facilities to control interior runoff behind levees and floodwalls. Interior flooding occurs when there is excessive seepage through levees, lack of adequate ditches, undersized gravity drains, insufficient pumping capacity, or just poorly drained soil. Coastal flooding can be caused by unusually high tides, storms, hurricanes, and tsunamis -- which are large waves caused by storms, and underwater seismic and volcanic activity.

Flood probability. Flood probabilities are indicators of how often floods exceeding a given magnitude might be expected to occur. Notwithstanding the influence of meterological cycles, floods are assumed to be independent events for purposes of hydrologic analysis. Because of this independence, if there is a flood level that is estimated to have one chance in 10 (10%) of being exceeded in any one year, it does not mean that another flood of the same magnitude is any more likely to occur in the following year, nor will it necessarily be another ten years before this level will be exceeded again. Floods and other random events do not occur in regular patterns.

HYDROLOGIC AND HYDRAULIC ENGINEERING

Economic analysis of any potential flood project requires an understanding of the basic principles of hydrologic and hydraulic engineering. These principles explain how flood damages occur and how damage reduction measures work.

Hydrology is the science of water cycles. Hydrology traces the movement of water from precipitation, infiltration, runoff and routing, to evaporation. Hydrologists use historical records as well as physical and conceptual models to estimate the magnitude and frequencies of various components of the water cycle.

Hydraulics is the science of laws governing the movement of water. Fluvial hydraulics is the science of the movement of water through stream and river channels. The hydraulic engineers are primarily concerned with the relationship between discharge--the rate water moves through a stream--and stage, the elevation of water above or below a specified level. Hydraulic engineers are involved with the design of structures to accomplish water related functions such as open channel flow and sediment transport.

The realm of hydrology and hydraulics are very intertwined both institutionally and physically in the real world. There is no fine line that distinquishes between responsibilities of the two disiplines. Planning is best served when both hydrologist and hydraulic engineers are involved throughout the process.

Precipitation patterns and the amount of rainfall for single events are traced with precipitation gages. These gages are placed throughout a

basin where they can be read manually or automatically and the data made available to offices responsible for keeping records and issuing flood warnings. Automatic gages are particularly useful for warning and preparedness programs, where continual monitoring is critical for timely and accurate forecasts. Inaccurate rain gage readings can be attributed to the effects of wind, topography near the gaging site, instrument malfunctions, and reading errors. Redundancy, or a high concentration of gages, will minimize the effect of the errors.

Precipitation frequency is the number of times that a precipitation of a certain magnitude can be expected to be exceeded in a given period of time. Precipitation frequencies, although sometimes appearing to be in cycles, can be expected to remain consistent in the long run. While hydrologic and hydraulic conditions, such as runoff patterns and stream channel dimensions are much more volatile.

Loss rates. The contribution of precipitation to flood conditions depends on the quantity and the speed of runoff. There is a percentage of water that will not run off into a stream or river, but is lost through infiltration, storage, or evaporation with any storm or snow melt. The amount of infiltration into the soil is determined by the soil type, slope, the amount of urban development, the vegetative coverage, the extent that the soil is already saturated by previous precipitation and drainage conditions, and duration and rate of precipitation: 1) Soils with high sand, gravel, and silt content allow much more infiltration than those with high quantities of clay. 2) Roofs, streets and highways, and parking areas that accompany urban development allow very little infiltration and greatly increase the speed of surface runoff.

3) Vegetative ground cover, which has seasonal effects, increases the amount of infiltration. Trees take in and retain more water than grass because of their extensive root structures. Deciduous trees and grass both take in less water while they are dormant in the winter. Vegetation also contributes to losses through evapotranspiration. As plants give moisture back into the atmosphere, they are able to take in more water. 4) Finally, the amount of moisture a soil already contains will determine the amount of additional water it will be able to absorb.

Runoff or Rainfall Excess is the total amount of precipitation, minus losses that occur from infiltration, storage, and evaporation. The contribution of runoff to stream flow is measured in cubic feet per second (CFS).

Urban development increases the surface impervious to water, which increases runoff and peak flows, particularly for low frequency events. However, in many urban situations the principal reason why flood peaks are higher than under rural conditions is because urban areas have more efficient conveyance systems: slick, straight ditches, and smooth surfaces. Figure IV-1 illustrates the influence that development type can have in peak discharge for various frequecies of flood .

Storage occurs in shallow depressions, and retention areas, such as wet (always holding some water) and dry reservoirs, ponds, and small retention structures. Storage plays a part in determining the loss rate and, therefore, the amount of runoff from a storm event.

Base Flow. The base flow is the amount of water entering a stream or a river from lakes, wetlands, or groundwater, independent of any new precipitation.

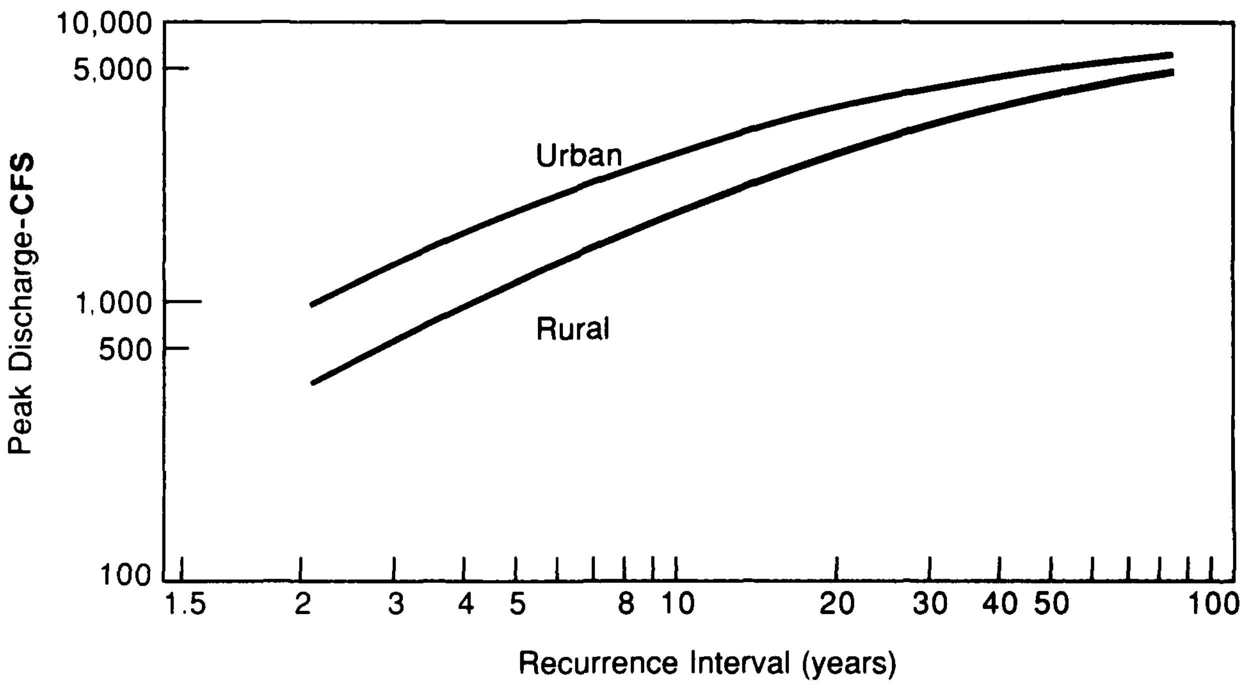


FIGURE IV-1 CHANGE IN PEAK DISCHARGE WITH URBANIZATION

Hydrograph Analysis. Hydrographs are diagrams representing the history of a flood's discharge or stage over the duration of an event. They are tools for representing the amount of discharge that occurs over time from a given amount of precipitation excess and base flow at an outlet or a given point along a stream.

Hydrographs illustrate the tremendous importance time can have in small drainage basins. High intensity storms, where large quantities of rainfall in short periods, can cause severe problems in small basins. Storms with the same amount of precipitation at different concentrations can vary greatly in what they contribute to peak flow.

Unit Hydrographs represent the quantity of flow from runoff that can be expected to reach an outlet point for each unit of runoff. A unit is for a given duration and amount. As long as the physical characteristics do not change, precipitation of the same duration and placement should have the same unit hydrograph.

Flood Hydrographs represent the quantity of discharge that would be generated from the runoff and base flow from a particular event.

Flood Hydrograph Routing is an engineering tool used to translate a flood hydrograph to some downstream point, and determine the change in shape of that hydrograph due to storage and conveyance capacity in the intervening reach. Some routing methods work only with flow. Others, called unsteady flow routing, work with both flow and stage. Routing may be used to determine the effect of any physical changes in a drainage area on the amount of discharge. Routing traces the movement of water through

streams, rivers, lakes, and reservoirs to determine this effect. Flood routing can be used for estimating the effects of changes at any one point on downstream locations.

Energy is the primary factor that affects velocity and discharge of instream flows. Potential energy will increase with drops in elevation. Bridges and other obstructions can contribute to energy loss. Energy at any point is defined as $V^2+D/2g$. Where V equals velocity, D is depth of water from stem bottom to water surface and g equals gravitational pull.

Geomorphology is the analysis of the natural process of land formations changing over time. Geomorphology tells how land form changes contribute in the long term to the dimensions of the stream, changes in energy, and other factors that influence discharge and stage. Geomorphic conditions may be greatly influenced by development and agriculture practices which add to the sediment load.

The level of sophistication in hydraulic study can vary appreciably, depending on the assumptions made regarding boundaries and flow. Mobile boundary hydraulics consider the changes in stream flow and channel dimensions that occur over time because of sediment size, supply, and transport potential. However, all but the most detailed studies assume rigid boundaries, with stream geometry that does not change appreciably over time.

FREQUENCY ANALYSIS

Flood probabilities are defined by several terms. These include: Percent Chance. This is the clearest, least confusing way of

describing flood probabilities. The 1-percent chance flood is a flood magnitude that has a 1-percent chance of being exceeded in any one year. It is sometimes called exceedance frequency (EF). Exceedance frequency is given by the formula:

$$EF = 1/(100-P)$$

where P is probability.

Recurrence Frequency. This is the average number of times an event of a given magnitude will be exceeded out of a total number, such as one time in 100 years. Recurrence frequency is numerically equivalent to percent chance.

Exceedance Interval (EI), Recurrence Interval, or Return Period. This has been the most frequently used term in defining probability. It indicates the average number of years between flood events. A 100-year event would have an average of one hundred years between each event that exceeds that level. Even though this definition is technically correct, it is misleading because the actual number of events will unlikely average out exactly as stated, even for high probability events over long periods of time. The exceedance interval is represented by the following formula:

$$EI = 100/EF$$

Exceedance Probability. This is the probability (P) of an event of a given magnitude being exceeded in any one year. A 1% flood is equivalent to a .01 probability. Exceedance probability is given by the formula:

$$P = EF/100$$

ANNUAL AND PARTIAL DURATION

Frequency distributions for flood peaks can be expressed in annual and partial duration series. The annual series measures only the largest single flood that might occur in any twelve month period. The partial duration series accounts for each damaging flood which is economically and hydrologically independent. Floods are hydrologically independent when they are caused by events with sufficient temporal separation to allow waters to recede below flood level before a new storm system which brings the river back up. Economically independent floods allow time for recovery, including structural repair and replacement of contents.

The annual series of peak flows is generally used for urban flood damage analysis. This is because the annual series is much less complicated and expensive to use, and succeeding events within any given year are assumed to cause little additional damage. Partial duration series are much more frequently applied to agricultural flooding where multiple patterns of flood peaks (recurrent flooding) in a year are considered much more critical. However, partial duration series might be considered in urban areas, where there is substantial damage potential in lower flood elevations and where the damage potential could be recovered in a short time.

IMPLICATIONS OF FLOOD FREQUENCY INFORMATION

Over time periods longer than one year, the risk of experiencing large floods increases in a nonadditive fashion. For example, the risk of exceeding a one percent chance flood one or more times during a 20-year

period is 25 percent, and 50 percent during a 70-year period. Table IV-1 illustrates probabilities for each of seven flood frequencies from a one percent to a 5 percent flood occurring anywhere from zero to 10 times during a 50-year period. The Table indicates that there is a 31 percent chance of a one-percent flood occurring exactly once in a 50 year period, a 39 percent chance of a one-percent flood occurring one or more times, and a 91 percent chance of a one-percent chance of a one-percent flood occurring one or fewer times during the same 50-year period.

Frequency distributions are computed by statistical analysis of recorded data. Streamflow data can be expected to become more reliable the longer the period of record becomes.

Flood frequency estimates can, in addition to annual or partial duration peak events, be developed for each season of the year and length of time flooding could occur.

Frequency distributions may be unreliable for places that experience flood events from a mixture of causes, such as snow melt and rainfall, inadequate or broken periods of record, or records that are incomplete because of events that may have been outside the gauge readings. Reliability problems may also occur when flood records have limited geographic coverage and when very few extreme events have been recorded.

The reliability of flood frequency curves is illustrated by confidence intervals. The hydrologist can say with 90 or 95 percent confidence that the true frequency lies within that confidence interval. A 90 percent confidence interval represents 1.645 standard deviations from the calculated frequency curve; a 95 percent confidence interval represents 1.96 standard deviations from the calculated frequency curve.

TABLE IV-1

PROBABILITY OF FLOOD FREQUENCY OCCURRENCE

FLOOD FREQUENCY PERCENT	FLOOD FREQUENCY YEARS	50 YEAR PROJECT LIFE RISK VALUES IN THREE WAYS FOR N=0 THRU 10 FLOODS N=0	N=1	N=2	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10
20.00	5.	0.	0.	0.	0.	1.	3.	6.	9.	12.	14.	14.
20.00	5.	100.	100.	100.	100.	99.	98.	95.	90.	81.	69.	56.
20.00	5.	0.	0.	0.	1.	2.	5.	10.	19.	31.	44.	58.
10.00	10.	1.	3.	8.	14.	18.	18.	15.	11.	6.	3.	2.
10.00	10.	100.	99.	97.	89.	75.	57.	38.	23.	12.	6.	2.
10.00	10.	1.	3.	11.	25.	43.	62.	77.	88.	94.	98.	99.
5.00	20.	8.	20.	26.	22.	14.	7.	3.	1.	0.	0.	0.
5.00	20.	100.	92.	72.	46.	24.	10.	4.	1.	0.	0.	0.
5.00	20.	8.	28.	54.	76.	90.	96.	99.	100.	100.	100.	100.
4.00	25.	13.	27.	28.	18.	9.	3.	1.	0.	0.	0.	0.
4.00	25.	100.	87.	60.	32.	14.	5.	1.	0.	0.	0.	0.
4.00	25.	13.	40.	68.	86.	95.	99.	100.	100.	100.	100.	100.
3.33	30.	18.	32.	27.	15.	6.	2.	0.	0.	0.	0.	0.
3.33	30.	100.	82.	50.	23.	8.	3.	1.	0.	0.	0.	0.
3.33	30.	18.	50.	77.	92.	97.	99.	100.	100.	100.	100.	100.
2.00	50.	36.	37.	19.	6.	1.	0.	0.	0.	0.	0.	0.
2.00	50.	100.	64.	26.	8.	2.	0.	0.	0.	0.	0.	0.
2.00	50.	36.	74.	92.	98.	100.	100.	100.	100.	100.	100.	100.
1.00	100.	61.	31.	8.	1.	0.	0.	0.	0.	0.	0.	0.
1.00	100.	100.	39.	9.	1.	0.	0.	0.	0.	0.	0.	0.
1.00	100.	61.	91.	99.	100.	100.	100.	100.	100.	100.	100.	100.

NOTE: The risk values are grouped in sets of three rows that correspond to:

Row 1 = Risk of exactly zero floods, exactly one flood,......, thru exactly 10 floods.
Row 2 = Risk of zero or more floods, one or more floods,......, thru 10 or more floods.
Row 3 = Risk of zero floods, one or fewer floods,......,thru 10 or fewer floods.

TABLE IV-1

PROBABILITY OF FLOOD FREQUENCY OCCURRENCE, Continued

FLOOD FREQUENCY			50 YEAR PROJECT LIFE RISK VALUES IN THREE WAYS FOR N=0 THRU 10 FLOODS									
PERCENT	YEARS	N=0	N=1	N=2	N=3	N=4	N=5	N=6	N=7	N=8	N=9	N=10
0.50	200.	78.	20.	2.	0.	0.	0.	0.	0.	0.	0.	0.
0.50	200.	100.	22.	3.	0.	0.	0.	0.	0.	0.	0.	0.
0.50	200.	78.	97.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.33	300.	85.	14.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.33	300.	100.	15.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.33	300.	85.	99.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.25	400.	88.	11.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	400.	100.	12.	1.	0.	0.	0.	0.	0.	0.	0.	0.
0.25	400.	88.	99.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.20	500.	90.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.20	500.	100.	10.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.20	500.	90.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.10	1000.	95.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.10	1000.	100.	5.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.10	1000.	95.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.50	2000.	98.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.50	2000.	100.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.50	2000.	98.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.
0.01	10000.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.01	10000.	100.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.01	10000.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.	100.

NOTE: The risk values are grouped in sets of three rows that correspond to:

Row 1 = Risk of exactly zero floods, exactly one flood,......, thru exactly 10 floods.
Row 2 = Risk of zero or more floods, one or more floods,......, thru 10 or more floods.
Row 3 = Risk of zero floods, one or fewer floods,......, thru 10 or fewer floods.

This assumes a normal distribution and an infinite number of observations. The size of the confidence intervals increase along with the number of standard deviations as the sample size decreases. A flood frequency curve for peak discharge is shown in Figure IV-2. It should be noted that the confidence bands get wider for more extreme events.

Additional details on basic hydrologic and hydraulic relationships used in flood damage assessment are given in Chapter V. Chapter VI illustrates how time and future development can alter those relationships. Chapter VIII describes the effect of flood control structures on those relationships.

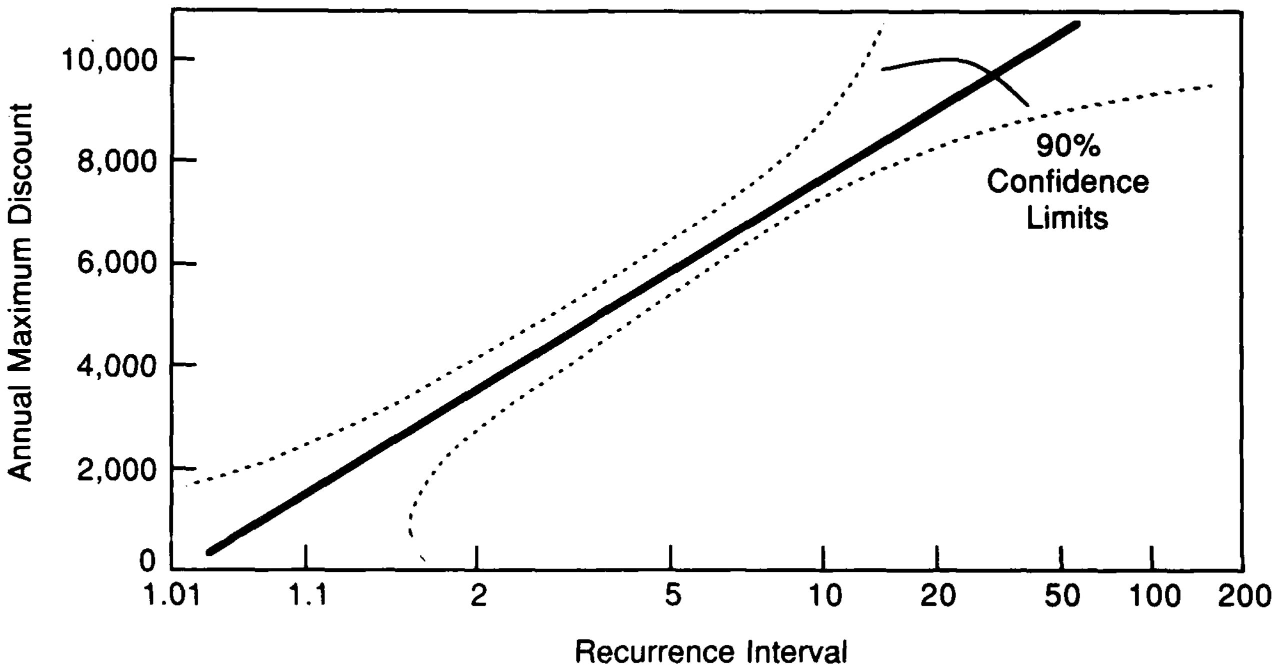


FIGURE IV-2 DISCHARGE - FREQUENCY CURVE WITH 90% CONFIDENCE INTERVALS

CHAPTER V

FLOOD DAMAGES FOR EXISTING CONDITIONS WITHOUT-PROJECT

This chapter traces the steps in defining the existing condition for flood damage analysis. The work described here is generally the most important stage in flood damage analysis. No planning of any sort can proceed before the work in this phase is complete. It is also the stage that is most clearly based on measurable variables, and thus it supplies the most compelling evidence of whether there is a need for a project.

Flood damages for existing conditions are expressed in terms of expected annual damages. Expected annual damages indicates the monetary value of physical loss that can be expected in any given year based on the magnitude and probability of losses from all possible events. Expected annual damages are derived by combining the information from three basic relationships: elevation-discharge and discharge-frequency which the hydrologic and hydraulic (H & H) engineers work with to compute the elevation frequency relationship, and elevation-damage relationship which is determined by the economist. Figure V-1 shows how the information in these three functions can be combined to calculate expected annual damage. An eight-step process for calculating expected annual damages is described in detail below. Figure V-2 shows the responsibilities of the economists and hydrologic and hydraulic engineers in computing expected annual damage.

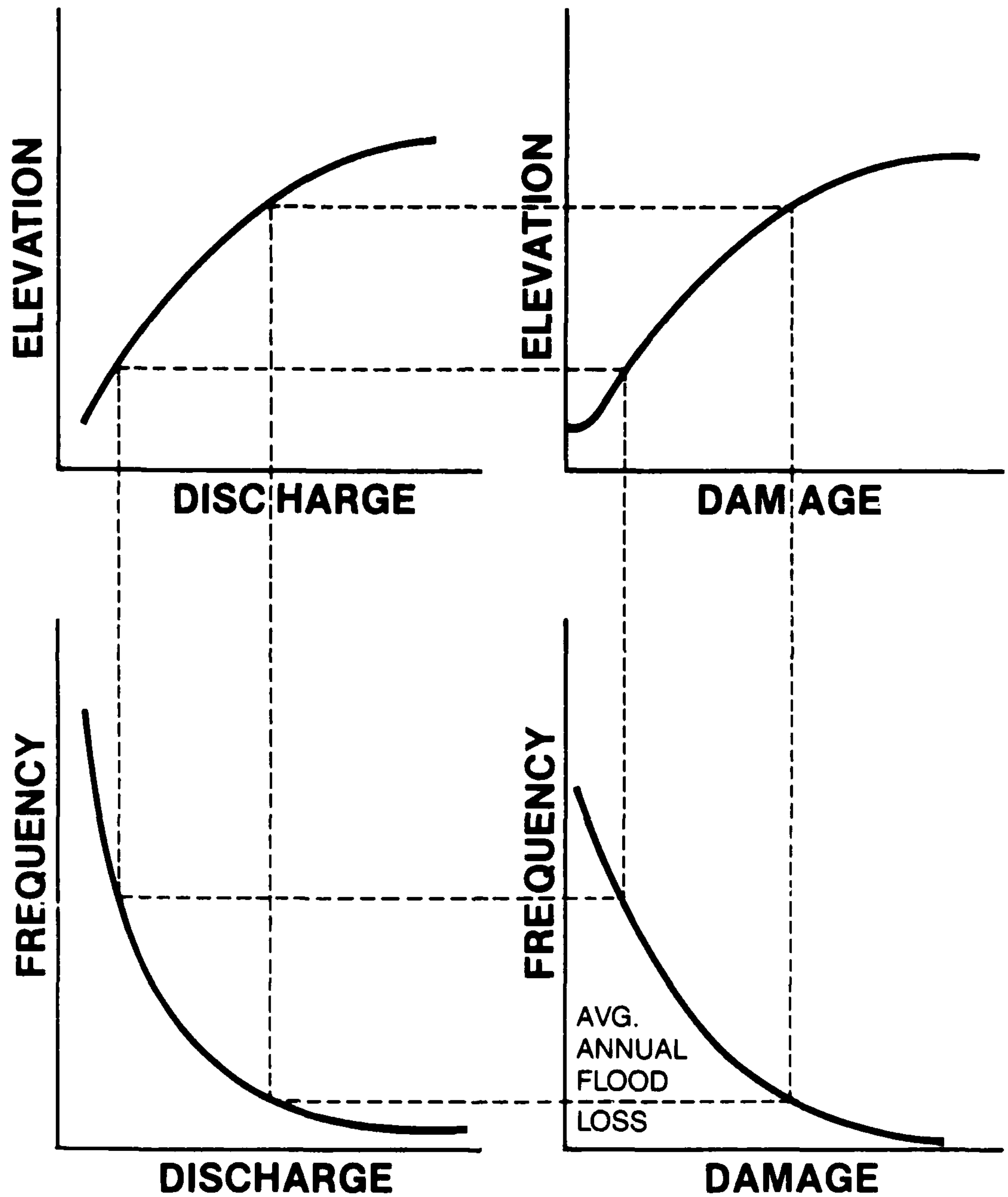


FIGURE V-1 FLOOD DAMAGE COMPUTATION

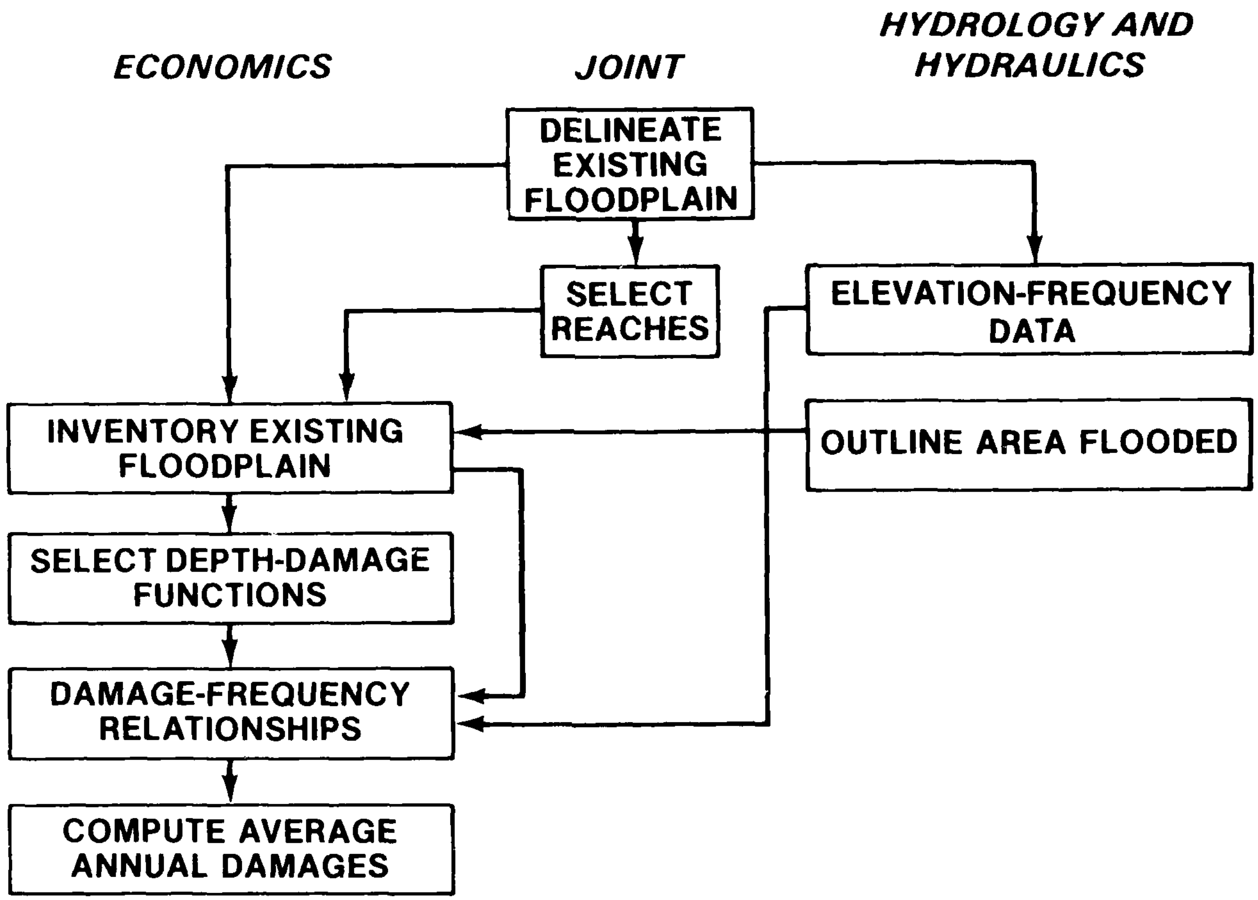


FIGURE V-2 RESPONSIBILITIES IN COMPUTING EXPECTED ANNUAL DAMAGES

STEP ONE: DELINEATE THE AFFECTED AREA

Definition. The affected area is that which is immediately or indirectly affected by the project. This is the geographic area that includes the floodplain and all alternate nearby areas that would attract development by a major activity, such as industrial or commercial construction. It also includes the area where development will influence runoff into the floodplain area.

It is during this phase of the study that the flooding problem should really be defined. Records should be consulted as to when damaging floods have occurred in the area; the areal and vertical extent of inundation should be determined; and hydrologists should gather information, for the period of record, on stream gauge and rainfall.

Use. The existing without-project condition must be properly identified since it is the basis for comparison with conditions projected with the plan. Existing flood control works should be taken into account when determining the degree of protection. An evaluation should be made of the effectiveness of any existing protection, and all other relevant systems expected to be implemented before construction.

Procedure. The first step in the process is to delineate the floodplain for detailed hydraulic and economic evaluation. The affected area consists of the floodplain, plus all other areas likely to serve as alternative sites for any activity which might use the floodplain if it were protected. This can be done by observation and recording of existing

land use, holding public meetings, reviewing local land use plans, and by consulting planners and other local officials, business leaders, and citizens' groups.

The descriptions of small drainage basins may cover the extent of flooding, land use, and business activities within the entire basin. For larger drainage basins, this description may be limited to the immediate area experiencing flooding problems, and nearby areas that are alternative sites for activities that are currently located in the floodplain. This description should include a history of the economic and social effects of flooding on the area. Dates, peak discharge, and peak stages of major flooding events should be given. When the information is available, the economic costs and categories of damages, as well as the number of deaths and injuries, should be noted. Information on flood events can be obtained from the National Weather Service, Corps emergency operations offices, and state and local emergency preparedness offices. Further information and contacts can be obtained from newspaper articles.

A critical part of defining the existing "without" condition is a proper evaluation of the degree of protection that existing flood protection can be expected to provide. The assessment involves two major considerations:

1) The first consideration is the level of protection that existing flood control works actually provide. In the case of an existing levee, design engineers will determine how much of the levee height is freeboard. Freeboard is the zone between the top of the levee and the design height.

Freeboard is a safety factor to account for unknowns such as wave action. Levees are generally credited for preventing one half the damages in the freeboard range.

2) The protection offered by any structure is dependent on its structural integrity. A project can only be considered effective insofar as it has structural integrity.

An existing levee cannot be considered as offering any protection at elevations above which inadequate structural quality would cause it to fail. Likewise, as discussed in Chapter VIII, there can be no benefits claimed for flood damage reduction attributable to replacement or rehabilitation of such structures unless it can be shown they are structurally deficient. Channels and interior drainage ditches should be sufficiently maintained so that sediment, logjams, and debris are not likely to cause a significant reduction of capacity. Structural investigations should indicate if levees are free of uneven settlement, inadequate seepage control, or deteriorated construction material.

STEP TWO: SELECT PLANNING REACHES

Definition. The reach is the primary unit of plan formulation. The river length and affected tributaries are divided into "reaches" throughout which the relation between discharge and stage remains practically constant, and into zones where development or use changes appreciably with stage. Frequency, flow, stage and damage data are used for each reach; thus data must be representative of the actual frequency

of flood events, flow regime and damage for that reach. A single reach may cover the entire developed area of a small community in which case it is known as a "damage center." Sub-reaches and zones may be established for the individual consideration of specific areas, particularly when on opposite banks of the stream or when separated by bridges or dams which appreciably affect local stage-discharge conditions.

Use. Reaches are the primary geographic unit for planning. Plans are formulated with components that cover a series of reaches. The H & H effects and subsequent benefits of a project are calculated for each reach. Consequently it is extremely important that reach selection be a joint effort by the project planner, the H&H engineers, and the economist.

The reaches, as defined by H&H considerations, are merely the distance between cross sections. Stream size, slope, and uniformity of the cross section shape are primary factors in determining the number of cross sections. From the economists' point of view, reaches are established primarily for the purposes of plan evaluation and display. Economists use reaches to determine the smallest breakdown of damages and benefits. Within each reach, breakdowns will be made of damages by land use category and flood zone as defined by flood frequency.

Floodplain management schemes often call for a combination of solutions. Solutions are based on changes, not only in hydraulic and physical considerations, but also on land use and political considerations. Reaches should be selected to help facilitate the formulation process by allowing breaks where there are significant changes in land use, changes in political subdivisions, and points where there may be changes in the types of floodplain management solutions.

Procedure. For each reach, an "index point" can be selected which will indicate the average relation between stage and discharge. In a rural reach, the "index point" may be the nearest established stream gaging station, at the nearest community, or a point near the center of the reach. In damage centers or developed areas, it may be necessary to make computations for a series of discharges in order to develop "rating curves" at several index points so that the sub-reach may be adequately evaluated.

Advancements in computer software and aerial photography have facilitated the use of flood profile methods for referencing the location of floodplain property and calculating damages. The profile method reference each structure to a specific location, usually within one-tenth of a mile of the distance from the mouth of the stream or river. Flood profiles that give elevations for the range of locations within the reach are then used to relate the frequency and elevation of flooding at each location. The profile method is more accurate than using index points because it takes into account any variations in the slope of the flood profiles within each reach, and instead of the average locations of the buildings within each reach, damages are calculated for specific location of each structure.

In addition to the technical considerations above, reaches and index points should be selected so as to permit separation and identification of damages and benefits in each political entity -- village, city, county or parish, and state. Ordinarily, this will not be found to increase the subdivision of reaches unduly, and the final summary may again combine

those subdivisions of which separate presentation is not warranted or desired.

Reach lengths are shortest where the physical, economic, and political factors are heterogenous. Areas with steep slopes and rapidly changing cross section geometry may have reach intervals every 1,000 ft. Reach segments along a major river may be over two miles long.

STEP THREE: ESTABLISH ELEVATION-FREQUENCY RELATIONSHIPS

Step Three is a series of three elements involving the primary portion of the hydrologic and hydraulic studies required in establishing the existing conditions. Step Three includes development of the stage-discharge curve, which is the basic hydraulic relationship; and the frequency-discharge curve, which is the basic hydrologic relationship. The elevation-frequency (or stage-frequency) relationship is the function derived by combining these two basic relationships.

Stage-Discharge Relationships

Definition. Stage-discharge relationships are functions that relate the amount of stream discharge (Q) to water surface elevations. Elevation is measured by the level of water above mean sea level (m.s.l.) or an established water surface level. Discharge is measured in number of cubic feet of water passing a gauging station in one second. Stage-discharge relationships are also known as rating curves. An example of a rating curve is shown in Figure V-3.

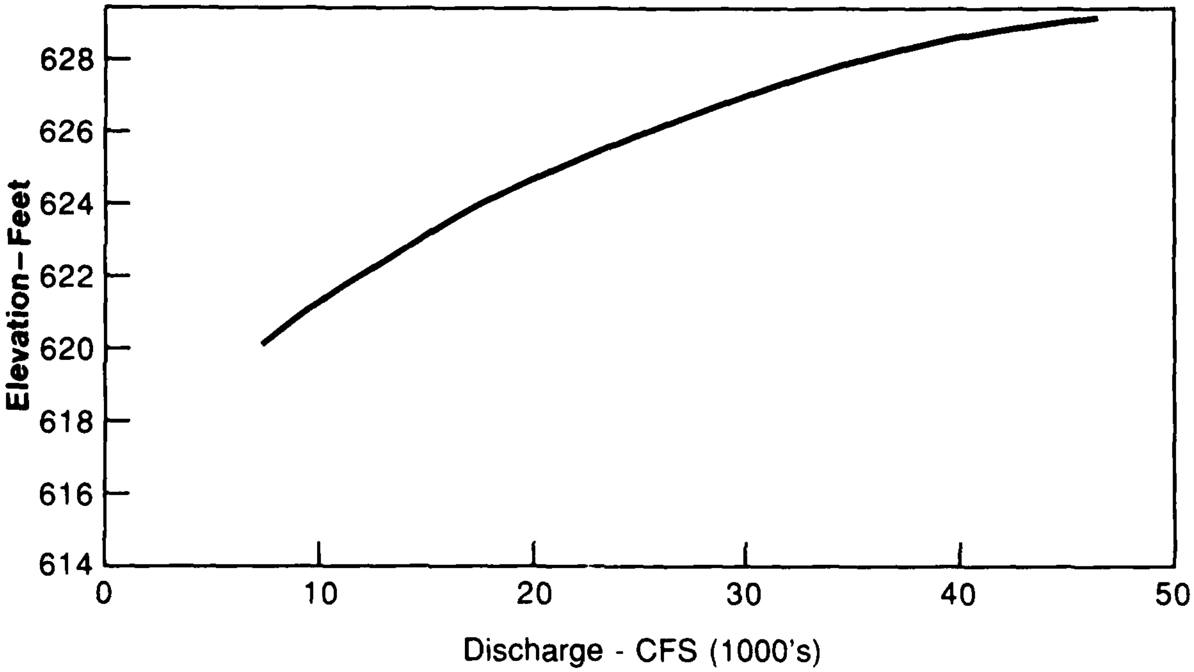


FIGURE V-3 ELEVATION - DISCHARGE (RATING) CURVE

Use. The primary purpose of an elevation-discharge relationship is for analysis to correlate discharge data with specific elevations to determine flooded areas.

Procedure. The procedures for establishing rating curves can range from adjustments of high water marks, as related to known peak discharge levels, to rigorous analysis by use of backwater computations. The detailed analytic calculation of water surface profiles, which is done for survey reports, requires the efforts of the hydraulic engineers.

The process requires the following steps:

1) Assemble the flow data from historic stream gage records;

2) Apply geometric measurements of stream cross sections from survey data (cross sections are measurements of the physical dimension of a stream at a given location). The number of necessary cross sections will increase with changes in topography, stream dimensions and other factors that contribute to changes in energy loss coefficients, described below.

3) Estimate energy loss coefficients to match observed data. Changes in the rate of energy loss can occur from the effects of newly constructed obstructions-- such as bridges, culverts and levees, changes in sediment and debris load, channel straightening, deepening, or silting. The observed coefficients can be supplemented or adjusted by judgments of the effects of changes and the applications of what has been learned from similar stream reaches.

Discharge-Frequency Relationship

Definition. A frequency is the number of occurrences that can be expected out of some possible number. For example, the exceedence

frequency of a 10,000 c.f.s. flood may be 10 times in 100 years. The same frequency can also be expressed as an exceedance probability, .1, or a flood with 10% chance of occurring in any particular year. Most often, the discharge-frequency relationship is expressed by its recurrence interval, which in this case would be a 10-year event.

Use. Frequency relationships are the key element in the criteria for establishing the magnitude of flood damage. No estimate of damage can be determined without first estimating how often any particular flood is expected to occur. Discharge-frequency relationships can be combined with discharge-elevation to establish the probability of each flood reaching a given elevation in any particular year. Figure V-4 is an example of a discharge-frequency relationship.

Procedure. The discharge-frequency relationship is estimated from three sources: 1) streamflow records, which give the maximum daily figure readings at stream gage sites for the period of record; 2) data from similar watersheds, which are used to identify patterns for unusual events and the reasonableness of estimates for the study area; and, 3) precipitation data, which are used to verify probability estimates. The accuracy of damage-frequency relationships can vary with the variability and understanding of climatic trends, randomness of the events, physical changes within the watershed, mixed combinations of rainstorms, snowmelt, and hurricanes, and the reliability of streamflow estimates.

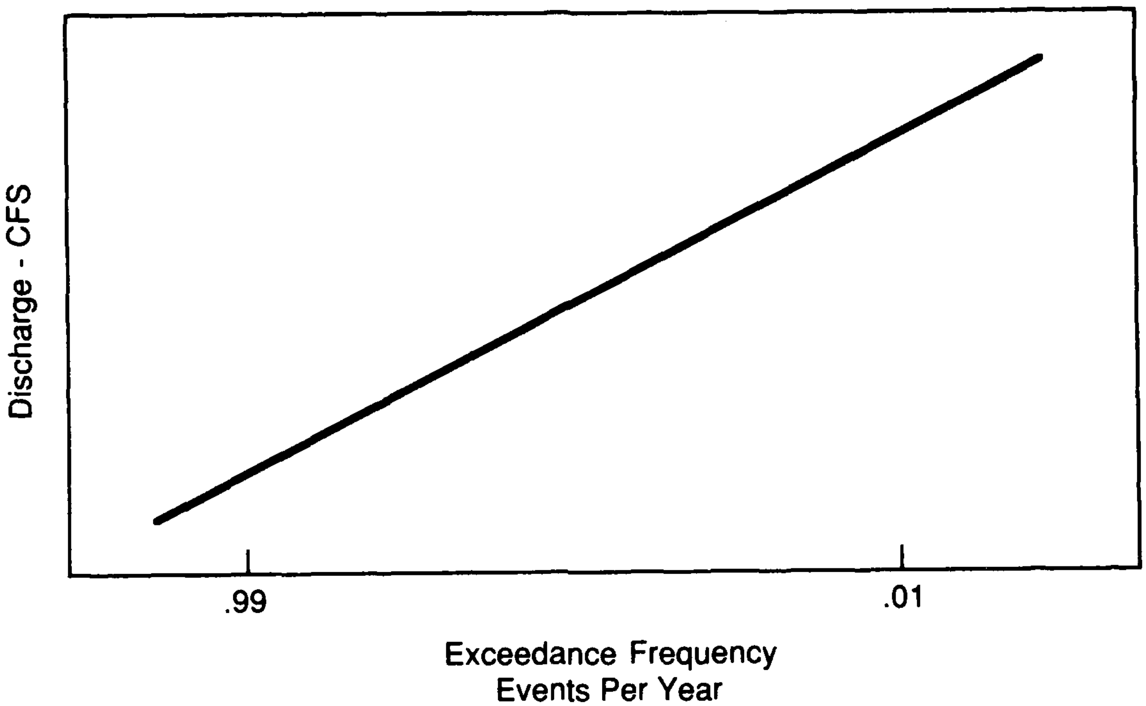


FIGURE V-4 DISCHARGE - FREQUENCY CURVE

Elevation-Frequency Curves

Definition. Hydraulic studies and observed streamflow data form the basis of the elevation-frequency curves, such as those shown in Figure V-5, which will be required for each reach for existing conditions and for each plan of local improvement considered ranging from zero damage stage to the Standard Project Flood.

Use. The elevation-frequency relationships are primarily tools of economic analysis. Selection of the basic data and derivation of the statistical relationships expressing flood frequency is a responsibility of both the hydrologist and economist.

Procedure. In previous paragraphs, derivation of elevation-discharge curves and discharge-frequency curves use is discussed. It is a simple matter to combine these relationships to establish the elevation frequency curves.

Elevation-frequency relationships require a combination of hydraulic and hydrologic information. The hydraulic engineering is mostly completed earlier, by computing rating curves. During that phase, water surface elevations are computed for levels of discharge. During this phase, it is necessary to calibrate frequencies to discharge.

Computation of elevation-frequency curves is a two step process, which consists of constructing elevation discharge curves from cross sections and topographic information, and using historic data and modeling to estimate discharge-frequency relationships. It is then a simple matter to combine these relationships to establish elevation-frequency curves.

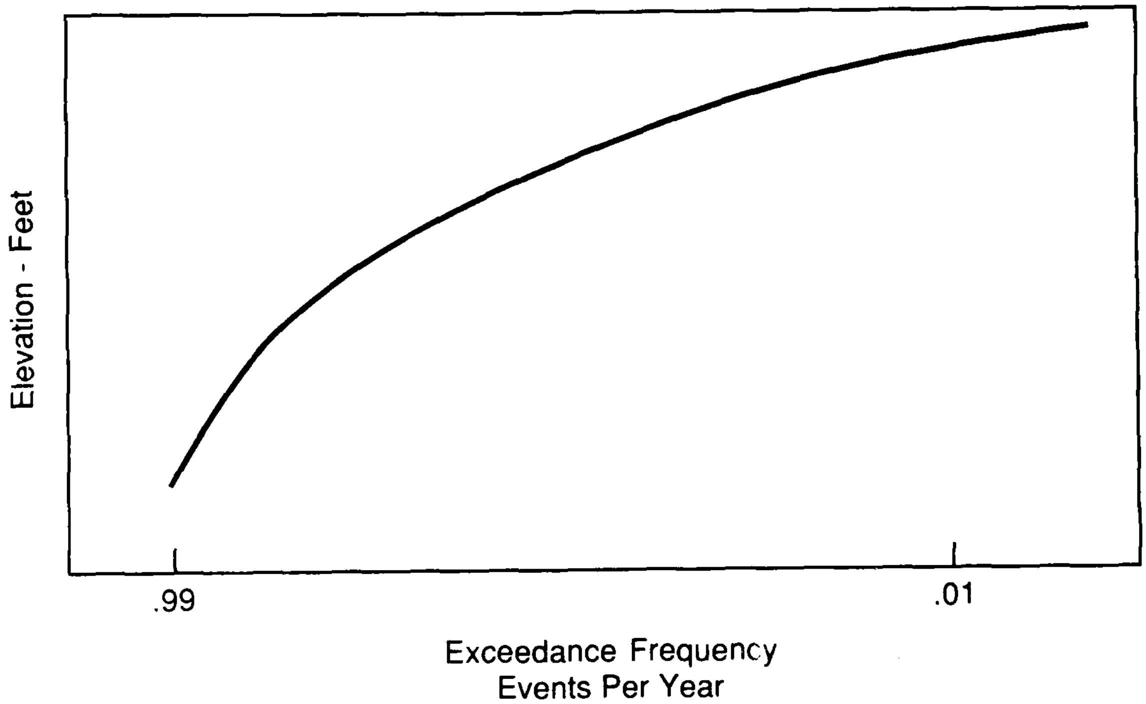


FIGURE V-5 ELEVATION - FREQUENCY CURVE

The hydrologist's role in calculating elevation-frequency relationships consists primarily of calculating the probability of various amounts of storm runoff entering a stream in a given period of time. The hydrologist's primary tool in establishing this relationship is the unit hydrograph. The hydrograph measures the workings of the hydrologic system. To make these calculations, the hydrologist needs historical records of rainfall, stream gauge levels and extent of flooding, and a land use study to determine how existing conditions may differ from conditions that led to historical events.

Hydrograph analysis then continues through a six step process, as follows:

1) The amount of rainfall is measured over time.
2) The amount of rainfall that is lost to infiltration into soils and other permeable surfaces over time is computed.
3) The amount of excess rainfall is calculated by subtracting the amount of infiltration losses from the amount of rainfall runoff.
4) The unit hydrograph is used to translate the amount of rainfall over time to the amount of surface runoff.
5) The base flow is computed by calculating the amount of runoff that would generally be present from all previous storms.
6) Total runoff is then computed by adding the amount of direct runoff to base flow.

STEP FOUR: OUTLINE AREA FLOODED

Definition. The area flooded simply refers to the geographic extent of flood inundation for one particular event or several magnitudes of flooding. At a minimum, the geographic extent of three areas should be shown: 1) the floodway, which is the natural storage area along the river or stream; 2) the one-percent chance (one hundred year) flood; and, 3) the SPF flood level. It may also be useful to show the limits of the flood of record (the largest flood recorded) or the most recent major flood. A map of the area flooded is shown in Figure V-6.

Use. The area flooded is outlined on a map primarily to let the economist know what floodplain property needs to be surveyed, and the degree of attention to give each area. Effort should not be wasted on surveying areas with too little expected average annual damage to support flood protection. Both the economist and the project planner can get a general idea in the early stages of planning of what type of project might be economically justified by observing the amount and type of property subject to flooding at various frequencies.

The floodway is important to identify because the National Flood Insurance Program mandates that participating communities completely restrict floodway development. Floodways are subject to particularly high velocities and subsequent danger for inhabitants. Floodway development along some streams can also raise water surface elevations for given frequencies of flooding.

The one-percent flood is important because of Federal Insurance Administration rules against development and rebuilding within that zone.

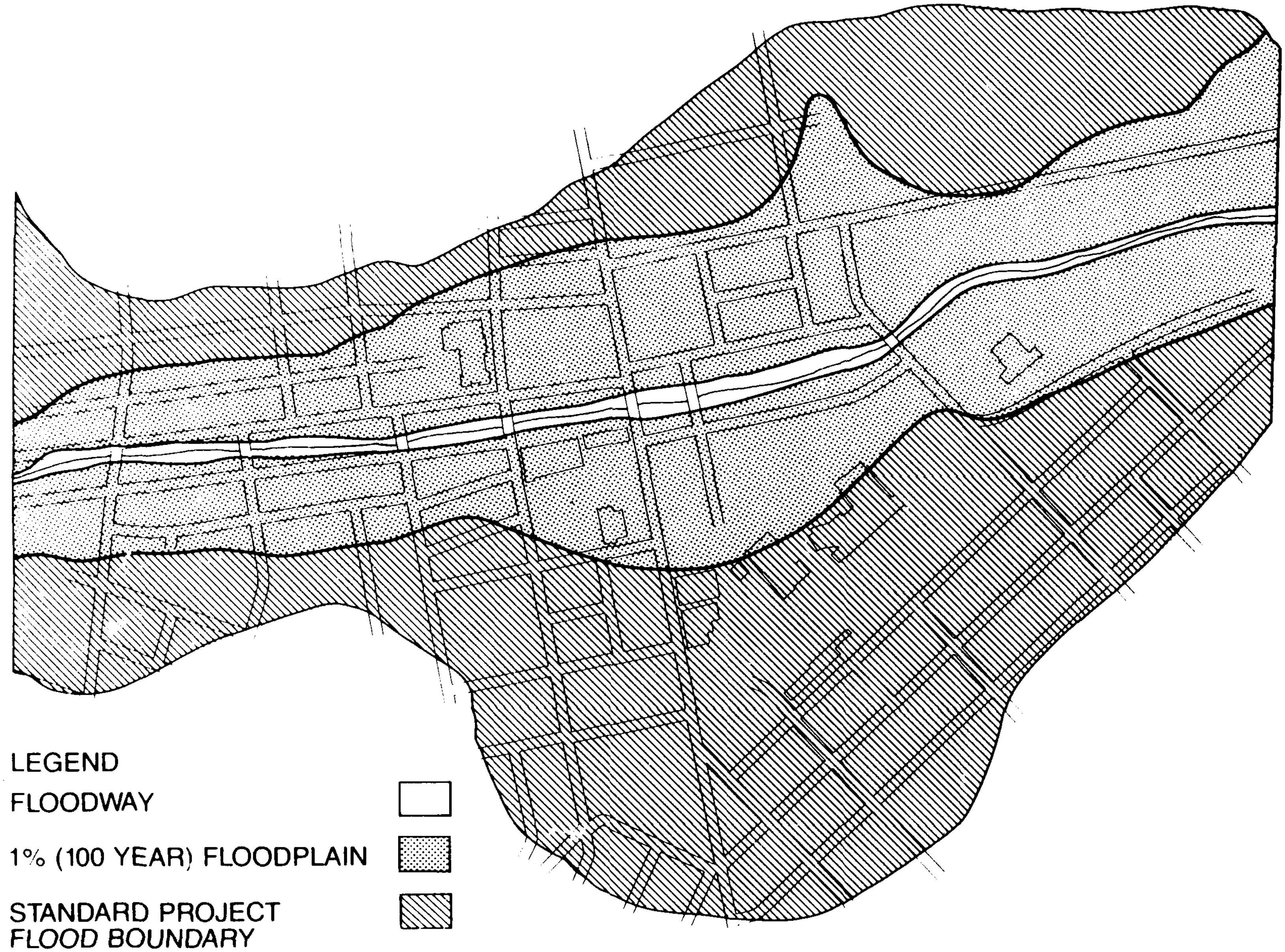


FIGURE V-6 OUTLINE OF FLOODPLAIN

The SPF is important because it constitutes the outer limits for any detailed study. Unless there is future development which will create run-off, and change the flood or flooding boundaries, and change the floodway boundaries, there is little reason to have detailed inventory of property outside the SPF boundaries.

Procedure. Elevation-frequency relationships at each cross section are utilized to outline the areas flooded at various frequencies of events. These areas should be delineated on topographic maps and aerial photographs. For most pre-authorization feasibility studies of urban areas, except where steep elevations and financial constraints prohibit, two-foot contour maps should be used to mark off the area flooded. Coastal floodplains may require one-foot contours. In other cases, such as Continuing Authorities and pre-authorization reconnaissance reports, it may be difficult to get more detailed than five-foot contours.

A field investigator should check the location of the overflow area tentatively outlined on the maps. This information should be substantiated by consultation with local engineers and other public works officials and from interviews with residents who have knowledge of the limits of previous floods.

Delineation of overflow areas may also be based on hydraulic backwater computations and correlations on topographic maps with known high water marks. The field investigator also needs to know as much as possible of the specific action and course of floods in each area, since the area subject to flooding and damages can vary appreciably with local circumstances and hydraulic conditions. Coordination with the hydrologic and hydraulic engineers studying the problem, and with local interests to

secure the results of their observation and experience, is an inseparable part of the procedure. Through the H&H studies, described above, and the topographic studies necessary to outline the floodplain, there is a degree of uncertainty as to where the limits of flooding would be for any particular flood event. Some of that uncertainty can be overcome through use of more detailed data and more precise procedures. Some of the sources of uncertainty are unavoidable and can only be acknowledged. The following conditions may be found to affect the limits and extent of overflow areas and damages:

1) Duration of flooding;
2) Filling and scouring of stream channels, outlets, and confluences during floods, to either increase or decrease channel capacity;
3) Observed or anticipated synchronization of flood peaks from several tributary areas;
4) Effects of buildings, streets, embankments, other obstacles and cuts on the course of flood flow;
5) Diversion of flood flows at various stages to other courses or channels, and the probability of erratic or unpredictable paths;
6) Contribution of sediment, debris, ice, and other blockages;
7) Local aggravating circumstances affecting overflow, such as dams, inadequate or clogged waterway openings, obstructions in channels, pervious and impervious embankments, pervious substratum, adequacy of local drainage and sewerage, inadequacy of existing levees, and backwater conditions in channels; and,
8) A major stream or a tributary changing course, and causing the flow of the water to take a different path.

The level of accuracy obtainable in the floodplain delineation is dependent on the accuracy of the flood profiles and the topographic information. The degree of accuracy required in delineation cannot go beyond what is available as part of the input data. In most instances, it would be a waste of resources to attempt to define the areas flooded by discharge to elevations closer than the nearest foot.

STEP FIVE: INVENTORY EXISTING FLOODPLAIN

This section illustrates the general procedures for inventory and appraisal of the floodplain. The inventory is to assess existing conditions and to estimate the potential of effects of any future growth. The procedures described here are applicable to residential, commercial, industrial, and public buildings, as well as transportation facilities, and utilities.

Definition. Inventorying is the surveying of floodplain properties to determine expected damage. Three types of information are needed for all property to be evaluated. These include: susceptibility classification, value, and elevation.

Use. The purpose of making an existing floodplain inventory is to learn what structures and other property are in the floodplain, the the value of structures and associated contents structures are, and at what elevation they are susceptible to flooding. This information is then used as a basic step in the computation of flood damages and flood damage reduction benefits. Structures include residential, commercial, industrial, and public. Physical damage estimates should also be made for

transportation facilities, public utilities, vehicles, communications and other outside property. The following sections will describe procedures for making damage inventories for each type of property.

Procedure. The information collected in the floodplain inventory should be tabulated for easy coding and processing by a computer flood damage analysis program such as those listed in Appendix C. All forms should be checked for accuracy, completeness, and legibility. Major steps in the inventory process include:

1) Reconnaissance is made to determine the representative property types or categories of properties in the floodplain;
2) Basic data from such sources as topographic maps or surveys, aerial photography, floodplain information reports, and flood insurance maps are consulted and summarized for referencing properties to flood stages;
3) An inventory or count of all properties is made in suitable observations and data recorded to facilitate application of sample data for the derivation of the stage-damage relation by the reach and zone;
4) Representative properties for adequate coverage of all property types in each flood reach and zone are selected, inspected, and appraised for real value and for damage potential;
5) Office analysis includes review of the field appraisals and inventories to obtain the stage-damage relations.

DEFINING STRUCTURE TYPE

Structure is defined here as a permanent building and everything that is permanently attached to it. For the purpose of floodplain inventory, categories of property are defined by similar susceptibility to flood damage. Both structural use and physical characteristics can be useful areas for categorization. The economists should make these distinctions based on the availability of existing depth-damage relationships of flood property with similar patterns of susceptibility to flood damage. Singe family residential building categories generally include the following: 1) one story, no basement; 2) one story, with basement; 3) two or more stories, no basement; 4) two or more stories, with basement; 5) split-level, no basement; 6) split-level, with basement; and, 7) mobile homes.

These categories can be further subdivided by wood, masonry, steel, or adobe structure; good, fair, or poor condition; and categories of size in square feet. The variable of building condition should have operational definitions for each classification. For example, Good Condition might be any property with visible repairs of less than 10% of the structure value. Poor Condition would be anything needing major structural repair of greater than 25% of the structure value. Fair Condition would be anything in between. Similarly, square footage categorizations of small, medium, and large should have operational definitions with number of square feet used as breaking points between size classifications.

1. Single family residential structures generally include single story with or without basements, two or more stories with or without basement, split level with or without basement, and mobile homes. Further

differentiations have been made for the type of foundation the building has, and extent to which the basement is finished and whether the basement might be more appropriately classified as being crawl space.

2. Multi-family residential structures can be divided by high-rise (more than ten stories), mid-rise (four to ten stories), garden apartments (one to three story walk-up units), duplexes and townhouses.

3. Commercial structures have the largest number of building use types. For structural damage potential inventories, it should be sufficient to have breakdowns by number of stories and relative size. These factors are often consistent for types of commercial enterprise, i.e. fast food restaurants are mostly one story buildings without basements, and have brick or block construction.

4. Industrial structures also vary by number of stories, building material, size, and permanently attached equipment. The value of individual industrial plants, variability of structural characteristics, operation, and output usually warrant detailed surveys of individual properties. Detailed surveys are also required in instances of unique structures and conditions.

5. Public buildings are defined here as public use -- rather than publicly owned. Public property includes public offices, schools, recreation facilities, hospital, churches, and nursing homes. Public offices, primary and secondary schools, and small churches are all housed in similar types of buildings, and should only require a brief windshield survey. Other public use facilities require detailed interviews and inspections to obtain value and susceptibility.

SAMPLING

It is recommended that every property be inventoried, at least by a windshield survey, to establish the approximate values and elevations, as well as the appropriate depth-damage relationships to use. Industrial property and larger commercial businesses require on-site inspections to determine the value and location of equipment, inventory, and outside property. For other types of property, sampling is an efficient means to verify windshield estimates of structure and content value as well as storage locations.

When proper field sampling procedures are used, variances, confidence interval, and other statistical measures can be derived from the collected data. This information can assist the planner in developing sensitivity analyses, in determining optimal solutions, and in evaluating the confidence that can be placed in study results. If care is not maintained in the development and implementation of survey design and sampling procedures, biases can be introduced that can lead to spurious results. Some common sources of bias that need to be considered when conducting sample surveys of floodplain properties include: 1) sampling with unequal and unknown stratifications (e.g., only conducting household surveys during the daytime, excluding those households from the sample where no one is at home during this period); 2) measurement error (e.g., asking for only the replacement price paid for a damaged furnace, rather than obtaining all the information needed to estimate the depreciated replacement value of the damaged unit; 3) non-response (e.g., individuals who refuse to participate in a survey having different income levels than those who do participate; and 4) interviewer error (e.g., a particular

interviewer who consistently overestimates structure values). Concise delineation of study objectives and data needs, careful consideration of questionnaire design and sampling plans, and the provision of training and supervision to interviewers can minimize the potential for obtaining biased results.

The degree of precision for floodplain inventory depends on the resources available for the project, the availability of data, and the precision of other study components. Accurate appraisals and elevation in computing flood damage estimates, and considerable effort, should go into making and verifying estimates. Stratification of floodplain properties (e.g., by building use, construction type, and elevation) before sampling, can generally provide increased precision for a given sample size needed to provide a specified level of precision.

VALUE OF STRUCTURE

Building values should be evaluated as an estimate of depreciated replacement value of the structure. Outside building values and land values should be considered separately. Estimating actual replacement values, determining an expected life, and depreciating by deterioration can be a time-consuming and costly job. If resources are limited, depreciated replacement values of buildings can be approximated by market values. Market values can be obtained from the following sources of information:

1) Real estate assessment data. Nearly every municipality and county in the United States levies a real estate tax. Property values are assessed as a percent of market value. The appraisals are usually divided

by land and improvements. Residential improvements, such as homes and garages, are usually combined in one number. Commercial and industrial buildings are most often appraised separately. Whenever real estate assessments are used, care must be taken to determine the stated and unstated policy for establishing a percentage of market value to be used for the assessment. Real estate assessments must also be tested for consistency. For various reasons, the ratio of assessed value to actual market value can vary considerably. It often takes several years to update the appraisals of an entire community with first-hand information. Inflation factors are used at other times. Recent sale prices, opinions of real estate sales people, and first-hand appraisals, can all be used to test the validity and consistency of real estate assessments. Where consistent ratios are established, the assessments, assessment-to-value ratios, and structure-to-land ratios can be used to estimate the value of buildings.

2) Recent sales prices. The recorder of deeds and the assessor's office in most communities keep records of all the property sales that occur. These values are recorded as a matter of public record for property assessment and for establishing deeds, mortgages, and liens. Realtors are also usually very willing to offer their knowledge of recent sale prices and the asking prices of property currently on the market.

3) Depreciated replacement values. Another source for making appraisals used by several districts is the Marshall Valuation Service, published by Marshall and Swift. Marshall and Swift documents can be used for obtaining replacement costs for building construction in various parts of the country. Local construction cost multipliers are given by area of

of the country. Local construction cost multipliers are given by type of construction material for all states and large metropolitan areas and medium-size communities. Square and cubic foot construction costs are given for foundations, flooring, walls, roofing, heating systems, plumbing, and built-in appliances, as well as garages and outside property. The guides are updated quarterly and available in printed form or by computer. Care should be taken to limit valuation estimates to the depreciated conditions, otherwise benefits might be over estimations of values.

ELEVATION FOR EACH STRUCTURE

Building elevations are as important as hydraulic information for establishing project benefits, and they are also much easier to accurately establish. Often, this crucial variable is given too little attention.

SOURCES OF TOPOGRAPHIC INFORMATION

1) Topographic maps. The U.S. Geological Survey maintains complete topographic maps of the United States. These maps vary in age, scale, and contour intervals. The maps are continually updated, but they can be as much as 50 years old. Urban areas are most frequently updated. For most urban areas, maps are at a scale of 1 to 24,000, where one inch equals 2,000 feet. Urban areas in terrain with flat or moderate slope are usually mapped with five-foot contours.

2) Permanent bench marks. Permanent elevation bench marks can be fixed by circular metal disks hammered, bolted, or set with masonry into a street, bridge or building. Reference elevations may also be recorded for

positions on permanent structures such as a spot on a bridge or the top of a fire hydrant. Bench marks are kept by the U.S. Geological Survey, the Corps, the U.S.D.A. Forest Service and Soil Conservation Service, the Bureau of Reclamation, and the Tennessee Valley Authority.

3) Aerial photography. Aerial photos are a commonly used tool for creating detailed contour maps. The maps can be used with stereoscopic equipment and field checking to create two-foot contour maps.

4) Survey crews. Survey crews are the most accurate and most costly way of determining elevations of structures. Survey crews are useful for very high value property, such as industrial plants and large commercial establishments, where small differences in elevations can make large differences in damage estimates. Survey crews are also important in areas with few permanent bench marks and areas with steep topography. The costs of survey crews can be reduced by combining their structure elevation surveys with cross-section survey, and by limiting their work to spot elevations or reference marks every few blocks.

5) Hand levels. Hand levels are simple devices for estimating the elevations of structures. This small hand-held instrument can be used to take readings off bench marks and determine the first floor elevations of surrounding structures. The user needs no assistance, but simply uses the level to find a spot on the nearby building at eye level. Hand levels should be used in circuits to tie back into the original bench marks. This will serve to verify readings along the circuit.

6) Architectural drawings and site plans. Architects, developers, and community building permit officers may keep building records with first floor, ground and foundation elevations.

CONTENT INVENTORY PROCEDURES

Definitions: Categories for single-family residential content inventory can be much the same as the structural categories described above. These include one story, without basement; one story, with basement; two or more stories, without basement; two or more stories, with basement; split-level, without basement; split-level, with basement; and mobile home. Subcategories within these can be made on the basis of income for consideration in setting content-to-structure value ratios. Content-to-structure value ratios are also of major importance in setting categories for apartments. See discussion-of-content to structure ratios below.

CONTENT-TO-STRUCTURE VALUE RATIOS AND THE NEED FOR INVENTORY

The inventory of building content requires a good deal more site specific inspection and interviewing than structural inventory. Nearly all industrial property and many types of large commercial establishments require detailed interviews or on-site inspections to determine the value and elevations of flood-prone inventory, equipment, and raw material. At least some sampling is required to determine content/structure value ratios for all types of commercial property. No standard commercial content ratio can be applied across types of commercial enterprises.

Even residential property, where standard depth-damage relationships can be applied, it may be desirable to have a sampling to establish a content/structure value ratio. Insurance companies generally use a flat rate of 50 percent for a residential content-to-structure value ratio.

Residential insurance customers have the option of claiming higher content values if they have high valued furniture, clothing, electronic equipment, appliances, or art work. The affluence factor calculation, which is described in Chapter VI, is based on the principle that the content-to-structure value ratio increases with household income with or without a project. It can also be assumed that the basic necessities, such as clothing and appliances, and modest luxuries, such as televisions and stereos, make the ratio above 50 percent for very poor households. Apartment and small condominium dwellers can also be expected to keep mostly highly valued items, when space becomes a limiting factor.

Determining Content Value. Appraisal of content value requires far more detailed work than structural appraisal. While the depreciated value of a building can be easily approximated through the market, content appraisal is much more complicated. There is little market information that can be used to evaluate the real value of residential or business contents. Used household goods are not universally found in top condition, and then the uncertainty of quality tends to limit the value. Business content inventory is best left to the manager of the facility. When there is a property of major consequence or the manager is in doubt, an insurance appraiser can be contracted to estimate the depreciated replacement value. Industrial and commercial inventory should be valued at the cost to the business for acquisition and processing.

Establishing Content Elevations. Estimation of content elevation in relation to the first floor of structures is generally only required for synthetically constructed depth-damage functions, as described in Step Six. In other cases, the content location is already considered in the

depth-damage relationship. When any home or business has made a special effort to elevate the storage location, that factor should be considered in the inventory.

INVENTORY OF OUTSIDE PROPERTY

Damage to outside property can be very significant, particularly in flash floods and other high velocity situations. Even so, outside property is seldom given thorough evaluation. Consequently, no commonly used procedures have been established for estimating loss to outside property.

The following is a list of considerations for determining the value and susceptibility of outside property:

Outside Buildings. Garages, sheds, and other small buildings are particularly vulnerable to collapse or being washed away by swift current. The building material and value of these structures should be noted. Residential garages are often storage areas for electrical and mechanical equipment, subject to shorting out, corrosion, and rust.

Vehicles. In many cases, vehicles receive a major portion of flash-flood damage. Expected vehicle damage potential should be given a lot of attention where the flood warning lead time is six hours or less. It is important to not only consider the lead time, but the potential evacuation routes and likelihood that people are available to move the vehicles. Motor vehicles can suffer extensive damage from floods that barely reach the first floor level of nearby buildings. Even in situations where there is a sophisticated warning and preparedness system, there may not be enough lead time to move vehicles.

Sources of information on the number and age of vehicles in a community include: 1) the U.S. Census, which gives the percent of families with one vehicle, the percent of families with two or more vehicles by income group, and the average prices paid for these vehicles new and used; 2) R.L. Polk & Co. of Detroit, Michigan, which keeps records on the number cars and trucks in operation by age group; and, 3) the U.S. Department of Transportation, Federal Highway Administration, Highway Statistics, which gives the number of automobiles and other vehicles registered by state, and per 1,000 population by state. Aggregated national figures for the Census and Polk Company data as well as the statewide Highway administration data are published annually in the U.S. Bureau of Census, Statistical Abstract of the United States. Average value of vehicles are published annually in Ward's Automotive Yearbook. The number and value of vehicles parked in commercial and industrial areas can only be determined by on-site inventory. In any case, the average number of vehicles at any place is dependent on time, day, and season. The analyst should attempt to find an appropriate average.

PUBLIC UTILITIES

Public utilities can best be inventoried after review of any previous flood damage. It is important to determine what facilities might be particularly vulnerable. Otherwise, facilities might be too numerous to consider. When there is no record of previous flooding, then inventory should concentrate on above ground facilities that are sealed. Sewage treatment and water treatment plants are particularly vulnerable, as are

electric power substations, gas regulator stations, and storage facilities.

Transportation Facilities. Highways, streets, and bridges are particularly vulnerable to washing out or suffering wave damage. Bridges are vulnerable to damage by debris, particularly when the debris is being carried by very heavy current. The locations and elevations of especially vulnerable facilities should be determined after interviews with local public works and state highway managers. Railway beds and track are subject to being washed out when the track is overtopped. The elevation, length and number of tracks, particularly in low lying areas, need to be identified. An effort should also be made to inventory rail yard facilities and cars that might be kept in low lying areas.

STEP SIX: SELECT DEPTH-DAMAGE RELATIONSHIPS

After the inventory and appraisal of flood-prone property, the computation or selection of depth-damage relationships is the most important job the economist has in this area. This section will deal with the process of selection of appropriate depth-damage functions to meet the requirements of a particular situation. This section also includes a discussion of when it is appropriate to use generalized depth-damage relationships and when it is necessary to compute site specific functions. There will also be emphasis on the process of verifying and adapting depth-damage functions to serve as reliable predictors of specific flood problems.

Depth-damage relationships are based on the premise that water height, and its relationship to structure height, is the most important variable in determining the expected value of damage to buildings. Similar properties, constructed, furnished, and maintained alike, and exposed to the same flood stages and forces, may be assumed to incur damages in similar magnitudes or proportion to actual values. However, there are many factors that can explain the variations in the extent of flood damages. There is no widely accepted, quantified relationship in the United States between any of these factors and the extent of flood damage. In prior steps, floodwater elevations for various discharges were derived, along with the frequency with which to expect these flows. In this step, and in the next step, the objective is to determine how much damage occurs at various flood elevations. There are two basic approaches. The most accurate approach is to determine the damages that occurred during a recent flood, usually by conducting extensive interviews with floodplain residents and business proprietors. During the interviews, damages are also estimated for elevations above and below the flood of reference. This is still the preferred method of determining the elevation-damage curve. However, it is a time consuming and expensive process for most large floodplains. Consequently, it is not unusual to obtain stage-damage data by using generalized data in a computer-oriented analysis. This approach is described below.

Application. Predictable depth-damage relationships can be used to estimate the amount of damage from any given level of flooding, and consequently, to assess the benefits of flood damage alleviation. Depth-damage functions are used to compute the probable damage for a given

level of flooding. Functions are computed separately for structure and content for various categories of enterprise. The functions are predictors of either direct-dollar loss or percent of value lost through a flood event. Damage functions can be applied to structures on an individual basis or applied over a large number of properties with similar susceptibility.

Selection Criterion. The major criterion in selection of depth-damage functions is the similarity of susceptibility relationships. Damage functions are influenced by a number of variables. Variables found to be significant in regression analysis can be used in computing reliable depth-damage relationships. Table V-1 summarizes the major factors: hydrologic, structural, and institutional, that significantly influence the amount of damage. While most people involved in flood damage assessment are aware of most of these factors, it has been rare that any of these factors have been isolated as part of a predictive function. It is less difficult to apply functions where the factors are reasonably close to the situation to which they are being applied. For example depth-damage functions computed for the lower Missouri River may be very applicable to damage from flooding along the Missouri River, where there is similar velocity, duration, and sediment load.

Table V-1
VARIABLES THAT INFLUENCE THE DEPTH-DAMAGE RELATIONSHIP

VARIABLE	EFFECTS
Hydrologic Variables	
velocity	Velocity is a major factor aggravating structure and content damage. It limits time for emergency flood proofing and evacuation. Additional force creates greater danger of foundation collapse and forceful destruction of contents.
duration	Duration may be the most significant factor in the destruction of building fabric. Continued saturation will cause wood to warp and rot, tile to buckle, and metal objects and mechanical equipment to rust.
sediment	Sediment can be particularly damaging to the workings of mechanical equipment and can create cleanup problems.
frequency	Repeated saturations can have a cumulative effect on the deterioration of building fabric and the working of mechanical equipment.
Structural Variables	
building material	Steel frame and brick buildings tend to be more durable in withstanding inundation and less and susceptible to collapse than other material.
inside construction	Styrofoam and similar types of insulation are less susceptible to damage than fiberglass and wool fiber insulation. Most drywall and any plaster will crumble under prolonged inundation. Waterproof drywall will hold up for long periods of inundation. Paneling may be salvageable when other wall coverings are not.
condition	Even the best building materials can collapse under stress if the construction is poor or is in deteriorated condition. Building

	condition should be a major determinate of depreciated replacement value.
age	Age may not be a highly significant factor in itself, except that it may serve as an indicator of condition and building material. It would be more accurate to survey the other factors separately.
content location	Arrangement of contents is an important factor in determining depth-damage relationships. These relationships could be expected to be somewhat homogenous for commercial business, particularly chain stores. Industrial property should be surveyed individually to determine how the arrangement of contents will affect the depth-damage relationship.

Institutional Factors

flood warning	Major reductions in both content and structural loss can be made through flood fighting and evacuation activities when there is adequate warning.

Sources. Generalized damage functions are computed for either post-flood surveys or synthetic estimates. Generalized functions are sometimes as accurate as building-by-building estimates of susceptibility, but they should be field-checked whenever they are applied. Knowledge is required of the critical variables that could influence damages in the area where the generalized curves were derived, and in the area where they might be applied.

Post-flood damage surveys are the most accurate way to determine the susceptibility of any property to various levels of inundation. Limited availability of study funds and lack of specific authorization to study an area often result in the delay of survey for some time after a major

flood. Post-flood surveys should be done by following the questions found in the package of questions approved by the Office of Management and Budget (OMB) Synthetic damage functions are estimated flood values, calculated at hypothetical flood levels and conditions. Synthetic estimates are often necessary for areas with no recent flood experience. Any number of flood damage levels can be estimated. Because synthetic damage relationships are hypothetical, they should be done by people experienced in post-flood surveys, who are familiar with what is damaged in a flood.

RESIDENTIAL DAMAGE FUNCTIONS

Well accepted depth-damage relationships were established for several types of residential buildings by the Federal Insurance Administration in 1970 and 1974, by the Tennessee Valley Authority in 1979, and by several Corps' district offices. Standard relationships are more common for residential structures than other types of property, because residential property is considered to be more homogenous in susceptibility and layout of contents, and in the types of building materials used, than other kinds of property.

Any damage function must be tested for reasonableness -- in the office on the basis of theoretical assumptions -- and in the field on the basis of empirical tests, to determine how well specific data are matched. The theoretical check should meet the following assumptions:

1) Physical damage can begin when flood waters reach the lowest levels of a building, even if flood waters are below the ground level.

2) Basement or cellar damage may occur when flood stage rises above the floor due to backing up through drains, seepage through foundation walls, or when flow through doors and windows occur. The primary factors will be the design of the sewer system, the soil types (soils with high clay content will absorb and filter water much slower than soils with high sand or loam content), and building material (concrete foundations will be subject to less infiltration than cinder blocks). Water pressure can also cause cracks or collapse of building walls and foundations, especially if water has not entered the building.

3) Damages at the same stage in different floods may vary with seasonal flood characteristics. There may be seasonal differences in velocities, duration, silt, debris, and ice content. Estimated damages might be tied to these seasonal factors and the probabilities of floods occurring at any particular time of the year.

4) Changing trends in property use, such as the more intense use of properties (game rooms in the basement and the accumulation of residential electronic equipment) will affect the stage-damage relation, and produce significant differences in estimates of current and future conditions.

5) Generally, for low and moderate velocity flood occurrences, the magnitude of damages on furnished levels will increase most rapidly to 3 or 4 feet above floor level, with an appreciably slower rate of increase to the next floor level.

6) The mobility of some personal property should tend to reduce losses, particularly when there is sufficient warning time. However, some damages, even of mobile property, will probably be inevitable due to lack of warning lead time and variations in judgement.

BUSINESS DEPTH-DAMAGE FUNCTIONS

Definition of Building Type. The computation of depth-damage functions for business structures can vary a great deal from residential computation. The variation in building size, number of stories, and construction material can lead to a greater number of structure type definitions. Although permanently installed equipment is considered real estate and consequently would be treated as a permanent part of the building, equipment is most often treated as a separate damage category. Industrial building construction is often highly specialized, and may not lend itself to general classification, but may need to be treated strictly on an individual basis. Otherwise, business structure categories might include one story, without basement; one story, with basement; two stories, without basement; two stories, with basement; multiple stories, without basement; and multiple stories with basement. Further breakdown could be made for masonry, frame, and metal structure.

EVALUATION OF COMMERCIAL LOSSES

Reconnaissance of the flood area will indicate the nature of commercial development, and the extent to which sampling procedures may be applicable or specific inspection and appraisal required. For interviews and inspection, the questions in the set of OMB-approved questions may be used for, or adapted to, commercial properties.

Sampling and specific appraisal requirements. To the extent that reliable, generalized, simple stage-damage relationships can be

established for specific commercial activities, they may be used, if reliable adjustments can be based on readily available parameters such as size or value of store, stock, turnover, number of employees, etc. Sampling should be limited or not used where wide variations in property characteristics exist; direct methods of appraisal should then be employed. Large individual establishments, that constitute a major part of the total damage in the reach, may warrant special attention by the appraisers. Advance contact with such interests may be advisable, particularly to enable them to assemble data on property characteristics and damages, and to arrange to review these with company officials. As in evaluation of residential damages, but more critical in the case of business and industry, is the estimating of reasonable periods for rehabilitation of property and return to normal operating conditions.

Evaluation of Direct Physical Commercial Damages. Actual or potential damages can be estimated by the normal methods of estimating construction costs. Where available, repair bills, company records, etc., also provide an independent source. As in other cases of direct physical damages, losses attributable to floods must be separated from repair costs that restore accrued depreciation. Shortened physical life (accelerated depreciation) of damaged items, non-recurring damages, and those preventable by good housekeeping, prudent management, or prompt action upon receipt of flood warning, can be eliminated from estimates of prospective damages.

INDUSTRIAL PROPERTY

Industrial property includes the facilities for extracting, producing, manufacturing, and processing of commodities, where labor on and working of materials creates new products and new wealth. Direct physical flood damages to industrial property include the net physical losses of economic value to land, buildings, machinery equipment, materials, supplies, and other items used in the industry. Direct physical damages to industrial property include all net losses from deterioration or spoilage of raw material, processing material, or completed goods. In general, the magnitude of industrial activity, with respect to other values in a flood area, and the generally unique nature and features of each industrial enterprise, requires that separate and specific appraisals be made for each industrial plant or property. Sampling procedures and comparisons with other similar plants cannot be relied upon to give an accurate basis for evaluation of flood control projects, and may be used only when similar small industries constitute a representative group comparable with sample conditions and do not make up a critical portion of the total damage estimate. The specialized nature of each industry and its operations ideally requires both the cooperation and assistance of the industry itself in appraising potential flood damages, and an impartial and independent appraisal and review by the Corps of Engineers. Where specialists familiar with major types of industrial property involved in a study are not available in the Corps, reporting officers should obtain consultative service by independent, qualified experts in appraising industrial damage. These consultants should be familiar with the principles and criteria of project formulation

and evaluation of the Corps of Engineers, the effects of floods on the specific types of industries involved, and the physical and economic aspects of the industry. The reporting officers must be the judges, in the course of field investigation, as to the admissibility, soundness, accuracy, and completeness of estimates of industrial flood damages for use in project formulation and evaluation. Estimates by industry or consultants need not be fully accepted. Satisfactory reporting requires that adequate explanations be given for differences in assumptions and appraisals, so that proper consideration and review can be given to the major and determining items in an estimate.

EVALUATION OF PUBLIC DAMAGES

General: Public property, for purposes of damage appraisal, can be considered to include all property owned by the various agencies of government or by charitable associations for the service of the public. Public property damages are principally apparent in the form of direct physical damage, or in the physical costs associated with preventing cessation or insuring continuation of public services. Some loss of public income may be found in interruption of services provided on a reimbursable basis other than taxation. Other than streets which are classed with transportation facilities and public power stations, public goods and services that may be adversely affected by floods include all public buildings, churches, schools, libraries, museums and other educational facilities, hospitals, institutions, water supply systems, sewerage systems and treatment plants, pumping stations, fire and police

protection facilities, parks, recreational facilities, etc. Specific inspection and appraisal of damage potentials is required in each case.

Physical damages to public property can be readily evaluated by the restoration method of appraisal. Estimates of such damages and the costs of related emergency and normal services should be prepared in cooperation with the governmental or other agency involved. The highly variable nature of other public facilities makes use of a standard form generally impracticable, and notes thereon and appraisal computations should be adapted to each case. It may be found that many public facilities or services overlap several flood reaches or zones and that damages cannot readily be assigned to specific locations.

Thus, breaks at any one or several points in water supply or sewerage systems may produce equivalent associated losses to customers or taxpayers in other reaches or on high ground. Damage to public property such as streets, sidewalks, lighting, water and sewer connections, etc., may duplicate part of the appraisal of specific properties served.

DEPTH-DAMAGE FUNCTION CALCULATION

Depth damage functions can be calculated to various degrees of precision. The simplest method is merely to take the mean value of percent damage for each water height. The problems with this procedure include: the limitation of variation in percent damage to one variable: water height; there is limited information provided on the effect of outliers or extreme values of percent damage on the sample mean; there is no level of dispersion determined for the data; and, there is no parameter to show the strength of the independent variable, water height, in

explaining variation in the dependent variable, percent damage. The advantages of this approach are that it is easy and quick; water height has always been believed to have the most influence on physical damage; and the effect of outliers can still be limited by setting reasonable limits on the values to be used in the calculations.

Regression analysis can measure the effects of several variables on percent damage. The strength of any one variable can be estimated along with the strength of the entire model in explaining the variance of percent damage. Regression analysis with depth-damage data is difficult because of the problems in obtaining good measurements of all the important variables that influence percent damage.

STEP SEVEN: CALCULATE DAMAGE-REQUENCY RELATIONSHIPS

Definition: The damage-frequency relationship is a simple relationship that is represented by the probability that could be associated with any level of flood damage. This relationship is derived from stage-damage, stage-discharge, and discharge-frequency relationships.

Use: The damage-frequency relationship is the last step in the process before computing average annual damages. By applying a frequency interval to each level, a weighted average for each of these events can be computed. Damage-frequency relationships are basically an interim step used in computing average annual damages. However, the breakdown of information by damage reach is particularly useful for identifying the areas of most severe economic damage.

Categories: Damage-frequency relationships are aggregated for display by damage category and reach. Major land use categories can

include: residential, commercial, industrial, public use, utilities, and transportation.

Procedure: This relationship is derived after the stage and flow relationships have been combined with flow-frequency relationships to produce the elevation-frequency relationship, and the stage-frequency relationship is combined with the depth-damage relationship for each flood reach, zone and damage category. Figure V-7 gives the aggregated damage-frequency relationships for various damage categories.

STEP EIGHT: CALCULATE EXPECTED ANNUAL DAMAGES

Definition: The expected annual damage is the expected value of flood loss in any given year.

Use: Expected annual damages are the most tangible measure of the severity of the existing flood problem. Generally, any project that is economically justified on the basis of existing conditions will be justified in the future.

Procedure: Expected annual damages are calculated by computing the area under the damage-frequency curve. This is done mathematically by taking an integral of the function. It does not mean that this amount of damage will occur in any particular year, but rather that over a long period of time, the average amount of damage will tend to approach that amount.

Assessment of existing conditions includes the consideration of any structure that is already in place (See Step Five on inventory of the floodplain for an explanation of this process). There is no projection involved.

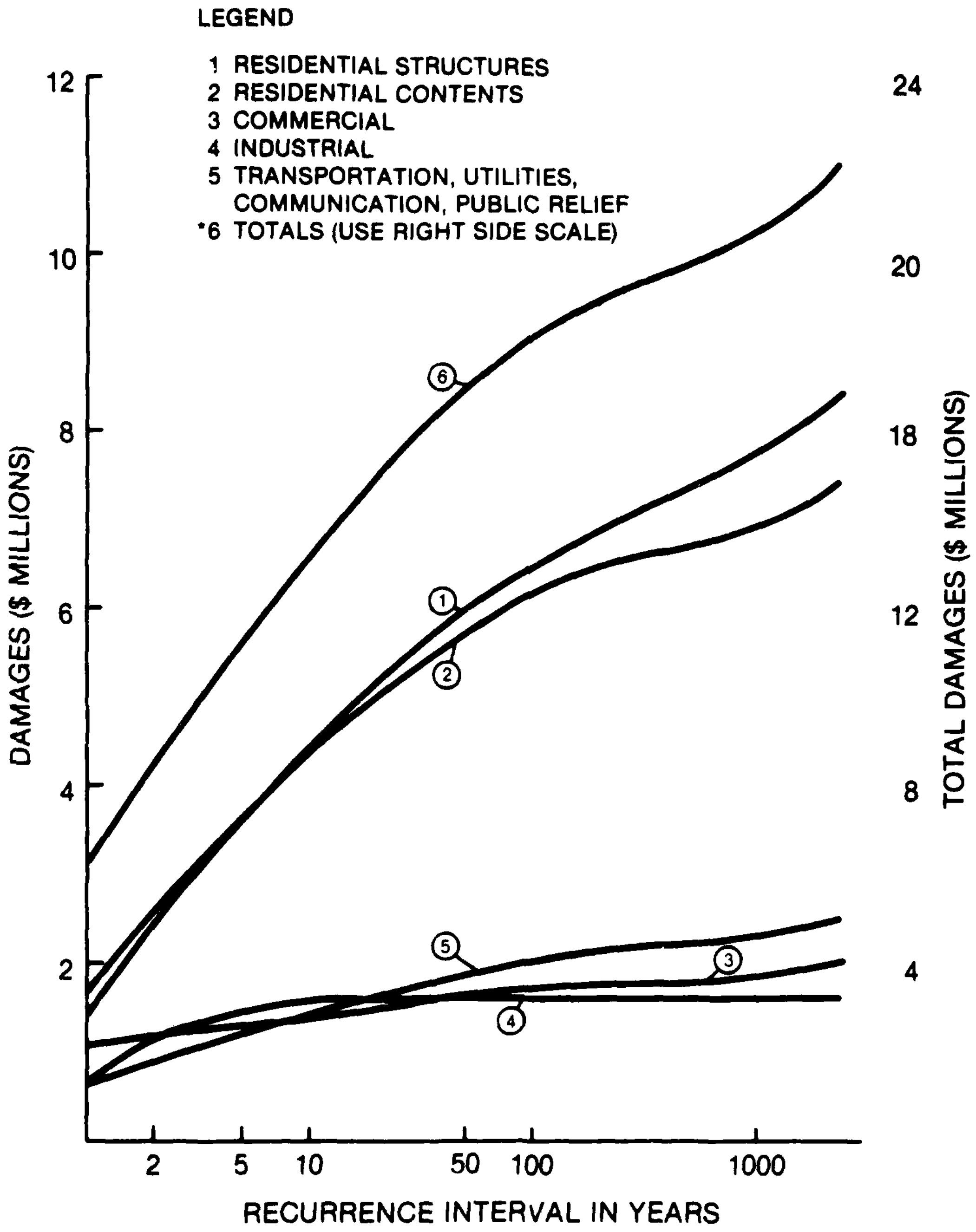


FIGURE V-7 DAMAGE - FREQUENCY CURVES

Expected values computed for frequencies in Step Eight are weighted by their exceedance probability. In most floodplain areas, the high frequency events usually account for the major share of the average annual flood damages. Damages for specific floods not computed in the damage frequency relationship are interpolated to create the function for expected annual damages.

Derivation-general: This is the method most frequently used by the Corps to compute expected annual damages. As will be seen later, it involves the combining of three basic functions: stage-damage, stage-discharge and discharge-frequency, to define a fourth function, the damage-frequency relationship. It has already been established how these functions are developed. Suffice it to say that the stage-damage curve, which relates dollar damage to each stage of flooding, is usually the responsibility of the economist and/or planner while development of the other two curves is usually the responsibility of the hydraulic and hydrologic engineer. This is not to imply that responsibilities should be performed independently of each other. On the contrary, as explained in earlier sections, team effort is necessary to insure internal consistency and consideration of all relevant economic and hydrologic factors.

Figure V-8 shows the relationships discussed above and the schematic for deriving expected annual damages. Stage-damage Curve A is combined with stage-discharge Curve B to generate damage-discharge Curve D by picking a damage point and relating it to a stage on Curve A, identifying the same stage and relating it to a discharge estimate on Curve B, and, finally, using the estimates identified for discharge and damages as a point on Curve D. This process is repeated until Curve D is traced out.

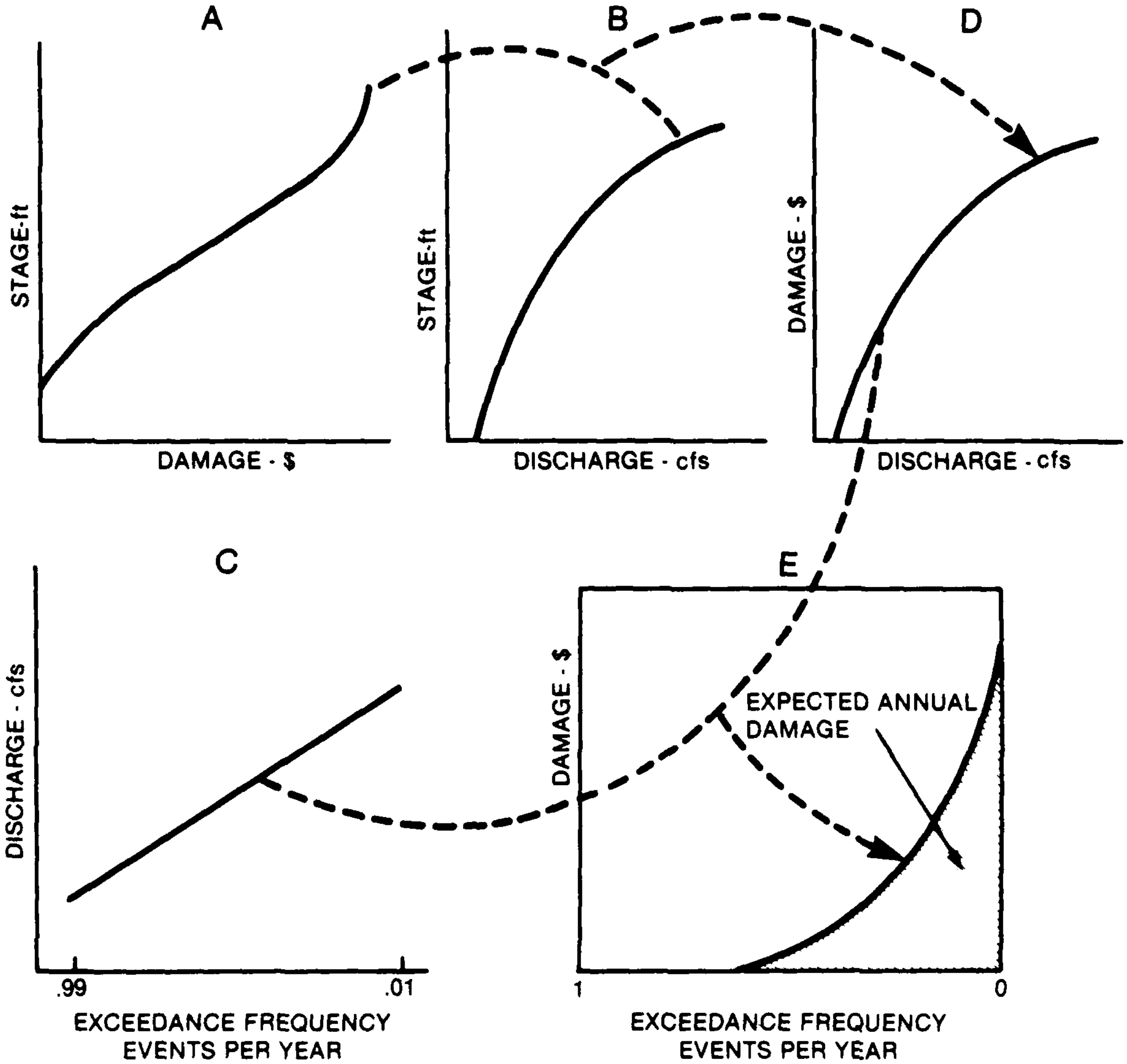


FIGURE V-8 SCHEMATIC FOR COMPUTATION OF EXPECTED ANNUAL DAMAGE

The tracing of Curve D is an intermediary step that is not necessary, but is included here to add clarity to the process. Curve D is then combined with Curve C to generate Curve E, the damage-frequency curve. The area under this curve represents expected annual damages. Subsequent paragraphs will show a sample computation, and will address the justification for both the procedure used and the conclusion that the area under the damage-frequency curve represents the expected annual value.

Sample Computation: Table V-2 displays a comprehensive picture of all the relationships used in damage evaluation. This is a standard calculation sheet that is designed to provide all relevant information. For example, if one wanted to know about a particular flood, e.g., the design flood, by reading across that row, it can be readily observed that the discharge is 10,000 cfs, the stage is 709.9 feet, the frequency is .6%, or a recurrence interval of 167 years (derived by dividing 100 by .6), and damages are $418,000. However, only the frequencies and damages, columns (5) and (7), enter directly into the computation of expected annual damages. Let us, therefore, concentrate on these columns, and the mechanics of computing expected annual damage. Column (6) represents the intervals between frequencies. For example, in the first row, .00135 (.135%) - .001 (.1%) = .00035, the first entry in column (6). This is done for successive pairs of frequencies, through the entire range. Next, we concentrate on column (7). The average damage between successive damage estimates is determined and shown in column (8), and results entered correspondingly with those in column (6). The entry of $652,200 in the first row is the average of $669,800 and $634,600. Corresponding values in columns (6) and (8) are then multiplied to give column (9).

TABLE V-2 - EXPECTED ANNUAL FLOOD DAMAGE COMPUTATION

STREAM ________________ REACH ________________

FLOOD	DISCHARGE (cfs)	STAGE (Ft.) RF	STAGE (Ft.) MSL	FREQUENCY %	FREQUENCY Interval	DAMAGES (Dollars) at stage	DAMAGES (Dollars) average	EXP. ANNUAL DAMAGES Interval	EXP. ANNUAL DAMAGES Summation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
SPF	26,300	+ 4.2	713.0	0.1		669,800			42,645
					.00035		652,200	228	
	22,750	+ 3.7	712.5	0.135		634,600			42,417
					.00040		616,100	246	
	19,500	+ 3.2	712.0	0.175		597,600			42,171
					.00065		578,600	376	
	16,600	+ 2.7	711.5	0.24		559,600			41,795
					.0006		539,100	323	
	14,300	+ 2.2	711.0	0.3		518,600			41,472
					.001		196,350	496	
	12,200	+ 1.7	710.5	0.4		474,100			40,976
					.002		446,050	892	
DESIGN	10,000	+ 1.1	709.9	0.6		418,000			40,084
					.0025		389,950	975	
	8,400	+ 0.6	709.4	0.85		361,900			39,109
					.0045		328,500	1,478	
NOV '87	6,800	RF	708.8	1.3		295,100			37,631
					.005		267,850	1,339	
	5,800	- 0.4	708.4	1.8		240,600			36,292
					.008		211,150	1,689	
	4,900	- 0.8	708.0	2.6		181,700			34,603
					.015		157,500	2,363	
SEPT '38	4,000	- 1.3	707.5	4.1		133,300			32,240
					.059		112,550	6,640	
	3,100	- 1.8	707.0	10		91,800			25,600
					.10		71,450	7,145	
	2,450	- 2.3	706.5	20		51,100			18,455
					.23		38,950	8,959	
	1,850	- 2.8	706.0	43		26,800			9,496
					.37		19,800	7,326	
	1,400	- 3.3	705.5	80		12,800			2,170
					.15		11,500	1,725	
	1,300	- 3.4	705.4	95		10,200			445
					.049		8,975	440	
	1,250	- 3.5	705.3	99.9		7,750			5
					.0009		5,150	5	
	1,240	- 3.6	705.2	99.99		2,550			0
					.0001			0	

Values in column (9) are then added cumulatively, starting from zero, to give the summation of the EAD of $42,645 shown in column (10).

Conceptual Framework for Computation: Ideally, the area under a continuous curve with a known function, $yk=f(x)$, can be determined by integrating over the limits of the intervals of that function. The concept of integration is based on breaking down the area under the curve into rectangles, computing the areas of these rectangles, and summing the results. The smaller the width of the rectangles (or the greater the number of rectangles), the closer this summation is to the actual area. A logical consequence of this is that if the number of rectangles approaches infinity, the area under the curve is essentially defined. This, then, is the basis for integration, and the justification for the procedure used by the Corps to compute EAD. The concept can be grasped more readily by examining Figure V-9. Damage-frequency points, taken from the simplified sample estimates shown in Table V-3, are used to construct the curve shown on this chart. The heights of the rectangles represent the average damages shown in column 4. For example, the heights of the first and last rectangles are 600,000 and 3,225,000, respectively. The widths of the rectangles are the frequency intervals shown in column 2. Consequently, the summation of the areas of all rectangles, i.e., the summation of all the heights times the bases, yields the same result as in the sample computation. However, it is well to remember that since the number of rectangles is limited, the estimate derived is only an approximation of the area under the curve. Estimates can be distorted, based on the number of input points, and on the shape of the curve, except where the damage-frequency curve is a straight-line. The straight-line damage-frequency

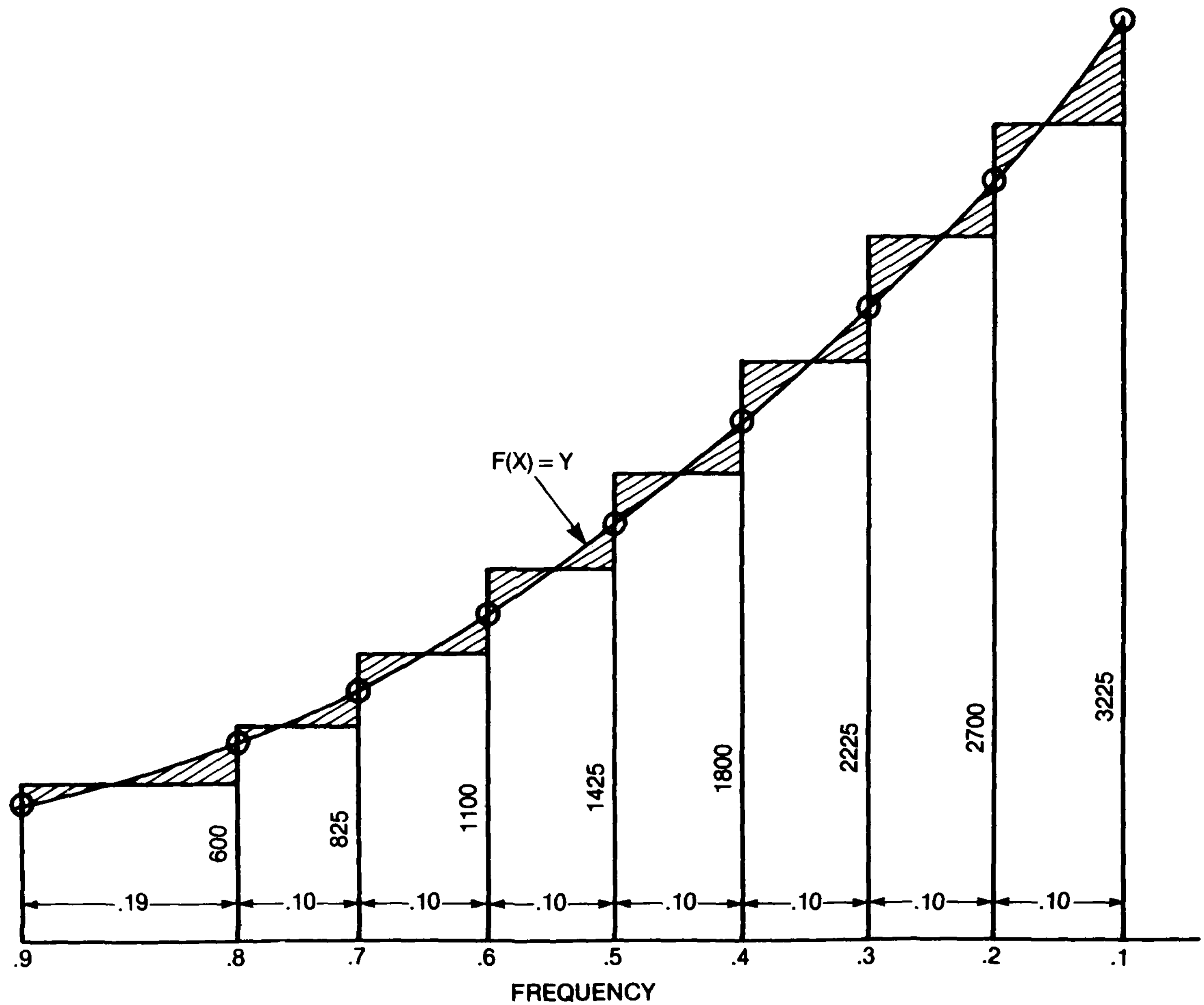


FIGURE V-9 INTEGRATION OF DAMAGE FREQUENCY CURVE

Table V-3 SAMPLE COMPUTATION OF EAD

		DAMAGES ('000)		EXPECTED ANNUAL DAMAGES	
Frequency	Interval	At Stage	Average	Interval	Summation
(1)	(2)	(3)	(4)	(5)	(6)
.10		3,500			1,445
	.10		3,225	322	
.20		2,950			1,123
	.10		2,700	270	
.30		2,450			853
	.10		2,225	223	
.40		2,000			630
	.10		1,800	180	
.50		1,600			450
	.10		1,425	143	
.60		1,250			307
	.10		1,100	110	
.70		950			197
	.10		825	83	
.80		750			114
	.19		600	1140	
.99		500			
1					

curve is an unlikely occurrence and is used here for illustrative purposes only. The simplified graph, shown on Figure V-10, has been further distorted to demonstrate the principles discussed above. Note that, by definition, frequencies range from zero to one. This figure should not, therefore, be construed to represent a realistic situation. It does, however, serve the intended purpose. The area under the curve is determined by three methods: by direct integration, by the frequency interval calculation method, and by directly computing the area from rectangles. Examples follow:

a. Direct Integration:

$$y = f(x) = bx+a$$
$$= 500x + 1000$$
$$\int_0^8 (500x + 1000)dx = [250x^2+1000x]$$
$$= [250(8)^2 + 1000]^8 - 0$$

Area = 16000 + 8000 = 24000

b. Frequency Interval Calculation Method:

x-Value Summation	Interval	Y-Value	Average	(2) x (4)	TOTAL
(1)	(2)	(3)	(4)	(5)	(6)
0		1000			24000
	2		1500	3000	21000
2		2000			
	2		2500	5000	16000
4		3000			
	2		3500	7000	9000
6		4000			
	2		4500	9000	0
8		5000			

Area = 24,000

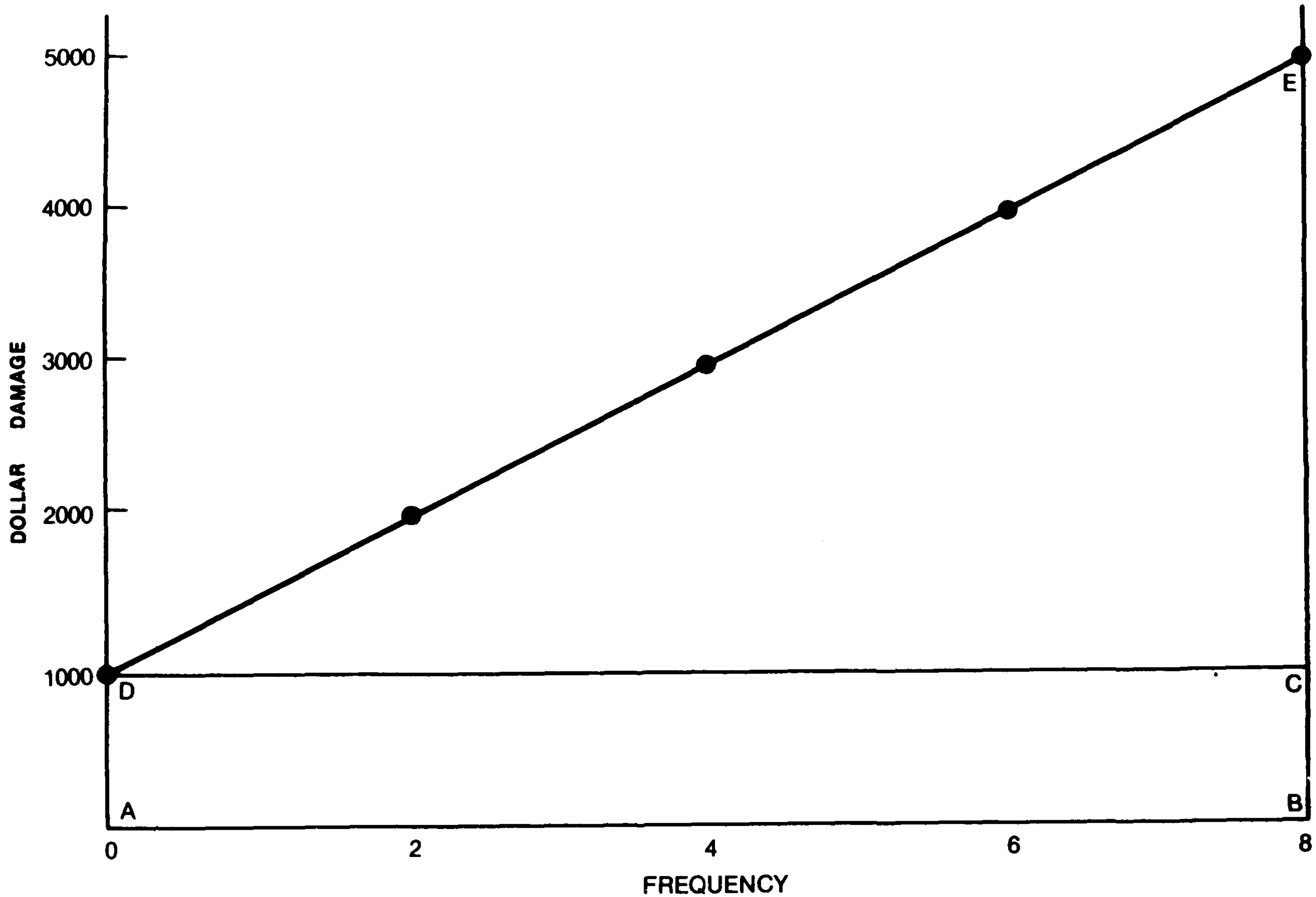


FIGURE V-10 STRAIGHT - LINE DAMAGE - FREQUENCY CURVE

c. Direct Computation:

Area of rectangle ABDC = height (h) x base (b)

= 1000 x 8 = 8,000

Area of triangle CDE = 1/2 (hb)

= 1/2 (4000 x 8) = 16,000

Total area = 8000 + 16000 = 24,000

The three methods yield identical results for the straight-line situation. However, for the typical non-linear situation, the closeness of results will depend on the number of input points and, therefore, on the number of rectangles defined by these points.

The second concern, regarding distortions from use of the frequency interval calculation method, can be demonstrated from an inspection of Figure V-11. Curve 4a duplicates the straight-line situation such that by inspection, the area excluded from rectangle ABCD, under the curve, is equal to the area included, above the curve. This, of course, is consistent with previous findings. Curve 4b is convex, and is more typical of the shape of damage-frequency curves encountered. Rectangle ABCD is fitted to the last two points. By inspection, it is observed that the area included in the rectangle, above the curve, is significantly larger than the area excluded, under the curve, such that the estimate for this part of the curve appears to be overstated. It appears, then, that the accuracy of the estimate is increasingly compromised the more convex the curve becomes. It can, therefore, be concluded that, typically,

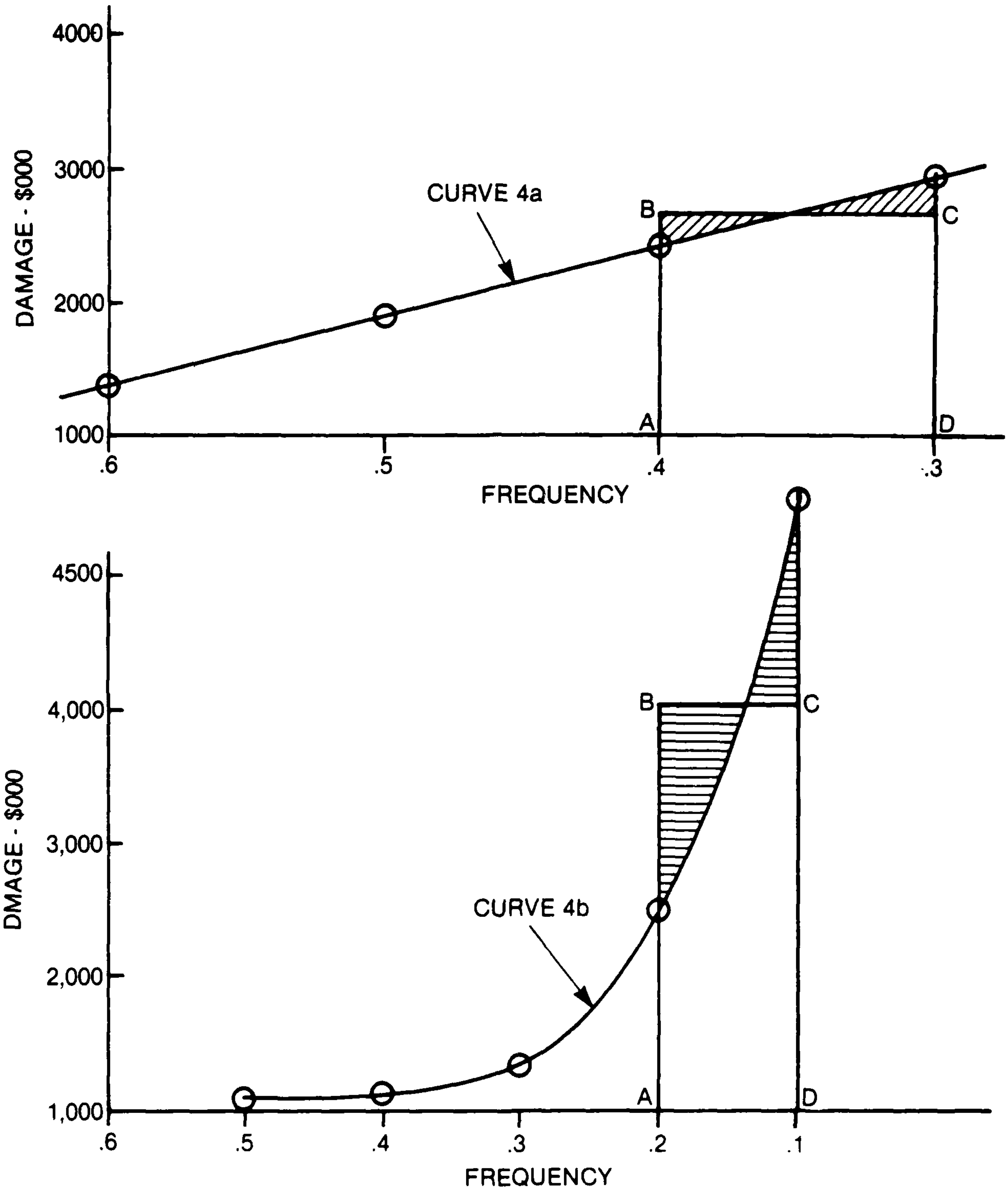


FIGURE V-11 DAMAGE - FREQUENCY CURVES

the frequency interval calculation method yields more accurate results for the lower end of the curve, which is usually flatter, and represents less frequent flood events, than for the upper part, which is usually more convex, and represents the more infrequent events. Even if it could be argued that, over the entire range of the curve, the pluses and minuses of areas tend to cancel each other out, EAD would still be distorted since the component of EAD contributed by more frequent events is more heavily weighted by the higher probability than those for the more infrequent events. Even so, we can conclude that if sufficient data points are used, the frequency interval calculation method will yield reasonably accurate results, since distortions occur primarily for the more remote events.

WHY EXPECTED ANNUAL DAMAGE?

It is important to know why the computed value is considered to be an annual value over the study period. The three basic functions used to determine the damage-frequency relationship, i.e., the stage-damage, stage-discharge, and discharge-frequency curves, under existing conditions, are derived based on existing hydrologic and economic conditions. The damage-frequency curve, employed in EAD computation, was generated from these three curves. In other words, the probability of occurrence of each event, in a given year, was used to define the probable damages in that year, based on the conditions that prevailed at that time. For example, the probable damages associated with a 100-year and a 10-year event are, respectively, .01 and .1 times the damages estimated for each of

these events in that year. The summation of all probable damages, over the range of events, defines expected damages for that year. This summation of probable damages is the same as EAD computed from the damage-frequency curve. However, to be considered an annual damage estimate over the period of analysis, essentially the same hydrologic and economic conditions must prevail over the period of analysis.

HEC EAD Program. Many planners use the HEC EAD program to compute annual damages. This can be done by directly inputting either the damage-frequency function, or the three basic functions from which the damage-frequency curve is derived. It is recommended that planners become familiar with the HEC Users Manual before using this program. This will help to reinforce your knowledge of the subject, will give an insight into how the program works, and will make you aware of some pitfalls to avoid when using the program. A word of caution is in order. The program inserts points between successive input points to more properly define a curve. For example, in the case of a damage-frequency curve, nine points are inserted between successive input points. It is important to emphasize that both the curve, and the EAD computed therefrom, vary according to the number of input points, consistent with the previous discussion. It is, therefore, incumbent on the planner to insure that sufficient points are inputted to properly define the relationship. This is especially critical where the study area has unusual characteristics that should be captured in the analysis. Additionally, program output should always be carefully checked for

reasonableness. One way is to check the results against recent flood events. A final word on this topic. Figure V-12 was taken from the 1984 HEC Users Manual. The dotted line shows the damage-frequency curve plotted by the HEC program from the nine input points. Note that for segment AB, the curves coincide; for segment CD, they almost coincide; but that for segment BC, there is a wide disparity. By inspection, the segment generated by the program does not seem to represent the best fit between points B and C. It appears that a better fit would be a curve somewhere between the hand and computer computations. This bias in the computer computations could be the determining factor in project feasibility. The planner would be justified in making an adjustment to the curve and to EAD in this analysis. Note, however, that this cannot be done without careful examination of the output.

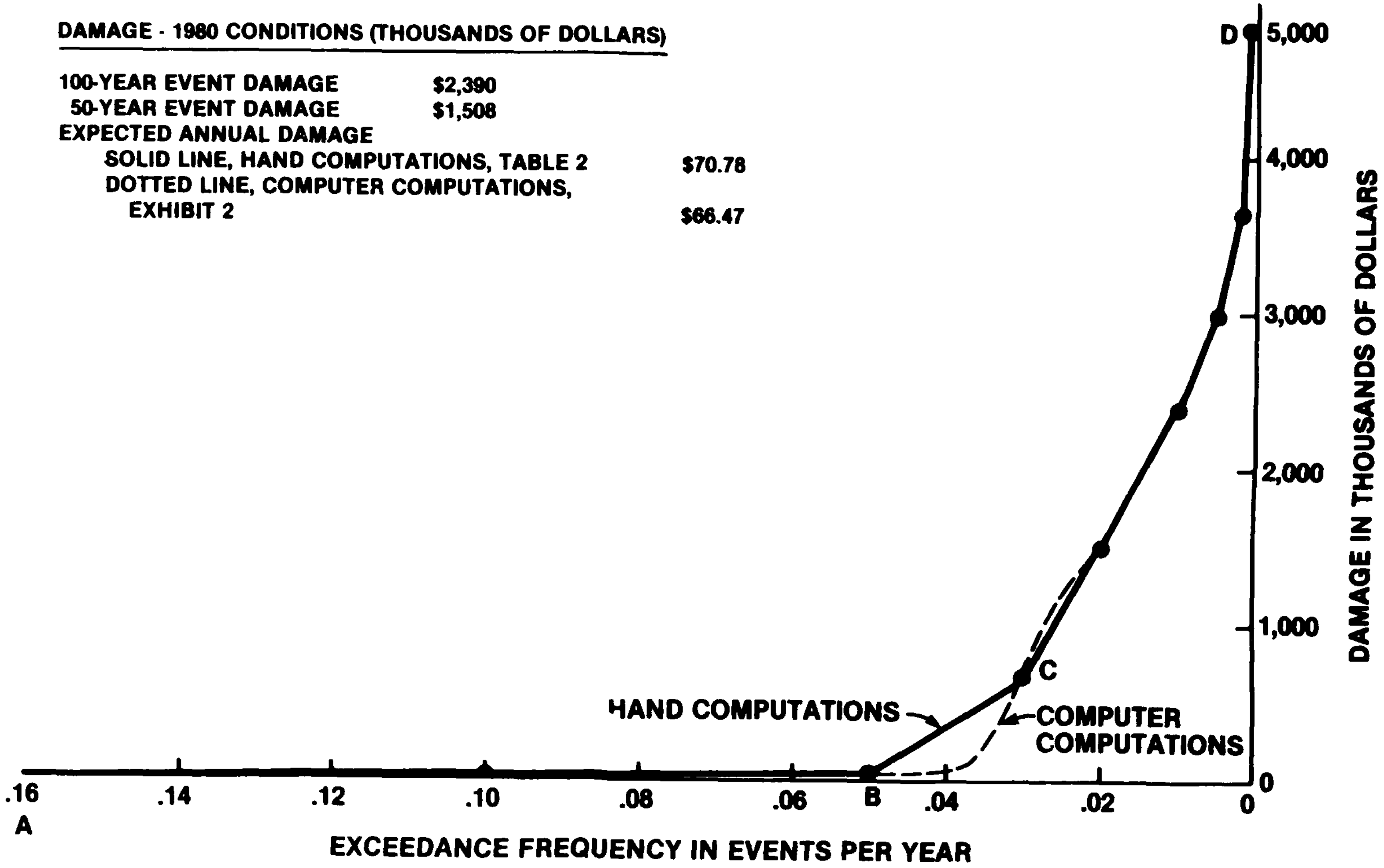


FIGURE V-12 DAMAGE - FREQUENCY RELATIONSHIP
DAMAGE CATEGORY: RESIDENTIAL STRUCTURES
REACH 1 PLAN 1 1980 CONDITION

CHAPTER VI

CALCULATION OF PHYSICAL FLOOD DAMAGE UNDER FUTURE CONDITIONS WITHOUT-PROJECT

OVERVIEW OF THE PROCESS

This chapter outlines the procedures used to account for all changes that would occur during the period of analysis if no project were undertaken in response to the study. According to P & G, "'future' is any time period after the year in which the study is completed" (P&G, p. 36). The period of analysis is defined as the project life, which is usually 50 or 100 years, depending on the type of flood damage reduction measure being considered. The period of analysis begins with the base year, when the project becomes fully operational. Due to the high degree of uncertainty over time, all economic activity, demographic, and hydraulic characteristics are held constant after the 50th year. All benefits are discounted to the base year. A large discount rate can greatly reduce the effect of any future changes on the overall project benefits.

This chapter describes how changes in land use, economic activity, and physical setting can affect flood damages. Projections have two major purposes: 1) to determine how changes in drainage patterns, that occur as a result of physical development, will affect elevation-frequency relationships; and, 2) to determine how changes in development and economic activity will affect elevation-damage relationships. These two relationships are combined to estimate damages under future without-project conditions. Hydrologic, demographic, and economic changes are

forecasts that are necessary for the base year, and for 10-year increments up to 50 years beyond the base year.

There are five steps in the process of analyzing future damages. These include: 1) establishing the economic and demographic data base; 2) projecting land use; 3) establishing new economic inventory; 4) estimating new elevation-frequency relationships; and, 5) calculating equivalent annual damages. Each of these stages are described in detail below.

CONDITIONS FOR ASSESSMENT

Any analysis of future conditions for with- or without-project conditions are subject to the following conditions:

1) All communities should be assumed to belong to the National Flood Insurance Program and in compliance with the following rules: a) no new development in the floodway, which is considered to be the natural storage area of the stream; b) the first floor of all new residential development must be above the one percent flood elevation; c) all new non-residential development must be above, or effectively floodproofed to, the one percent flood elevation; and, d) no major reconstruction or additions (equaling 50% or more of the structure value) to an existing property can occur without complying with rules b and c above.

2) Compliance with E.O. 11988 assumes that Federal agencies will not take actions that will promote development in the 100-year floodplain.

3) Decision makers are presumed to act rationally by assuming the most likely conditions that would occur under each measure. Rationality is based on the premise that individuals will continually act to maximize their net income. Irrational use, such as continued occupancy in

frequently flooded areas, will not be perpetuated. The rationality test for continued floodplain occupancy is whether the floodplain location offers advantages sufficient to offset the costs of any land use or building regulations, plus the costs of any residual flood damages.

4) Development conditions are never static. Property can be added to or removed from the floodplain. Frequently flooded property may be abandoned and removed over a period of years.

5) Other Federal projects that are authorized and not yet constructed, and non-Federal flood control projects that are planned and not yet constructed by state and local governments, should be evaluated according to the likelihood and projected date of their implementation.

6) If local action is planned to occur only as the result of no Federal action, the project should not be assumed as part of the "without" condition. Local interests should not be penalized for their own incentive.

Listed below are five basic steps in calculating inundation reduction benefits for future conditions without-project:

STEP ONE: ESTABLISH THE ECONOMIC AND DEMOGRAPHIC BASE

The analysis of future benefits without-project begins with a detailed study of population characteristics and the level of economic activity in the region. Projections for population and economic activity are made for several points into the future. Values for the intervening years would then be interpolated, with the values displayed for the 10th, 20th, 30th, 40th, and 50th year beyond the base year.

The primary source of projections, that is up-to-date, easily accessible, and identified by P & G is OBERS. OBERS stands for the Office of Business Economics (which is part of the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce) and the Economic Research Service (ERS) (which is part of the U.S. Department of Agriculture). The acronym has been preserved, even though ERS is no longer involved. OBERS is published every five years by BEA. OBERS projections are published for the Nation, each of the 50 states, the District of Columbia, and each of the 330 Standard Metropolitan Statistical Areas (SMSA). The 1985 publication includes figures for 1969, 1973, 1978, 1983, 1990, 1995, 2000, 2005, 2015, and 2035. The state figures include population and personal income, as well as earnings and employment for 57 industrial groups. Metropolitan earnings and employment figures are limited to 14 industrial groups. Further breakdowns of county data can be developed under contract to BEA. The aggregated figures for the study area should be equal to the figures defined by OBERS for the entire BEA region. Any exception to the OBERS projections should be supported by evidence of why projections for that area would be different, such as when major industrial development or a public institution is planned.

Projections of economic activity within the study area are based on three major factors: 1) the attributes of the study area; 2) the attributes sought after by potential activities; and, 3) the availability of sought after attributes in the surrounding area.

Potential future use should first be specified by broad categories including: residential, commercial, industrial, public use, open space, recreational, and agricultural (in areas that are likely to receive urban

development). Sufficient area must be included to insure that the affected area is at least large enough to accommodate these major categories of potential future uses. When the potential use of the floodplain includes industrial use within a metropolitan statistical area, the entire metropolitan statistical area is the affected area; for residential areas, even within a metropolitan statistical area, a much smaller area may be envisioned.

All problems and characteristics of the study area should be evaluated in terms of existing conditions and the base year. The base year can be estimated by the amount of time for the process of authorization, funding, and implementation. The period from submission of a plan to implementation can vary considerably, and delays are commonly part of the approval and funding process.

Several other attributes are critical for projecting what the floodplain inventory will consist of when land use changes take place. These attributes are generally assumed to remain constant, unless there is strong reason to expect demographic changes: 1) population per single or multi-family housing unit; 2) distribution of activities over the floodplain area; 3) natural population increase and net migration.

STEP TWO: PROJECT LAND USE CHANGES

Land use patterns within the basin form the basis for all economic and hydrologic change. Any planning study must contain estimates for past, existing, and future land uses. The scale of land use mapping will

be dependent on the nature of the project. The following describes seven steps in the land use projection and allocation process:

1) Review Federal Projections. The Office of Business Economics (OBE) and the Economic Research Service (ERS) of the calculate projections for states and metropolitan statistical areas. This set of projections is to serve as the primary source of demographic projections used by Corps of Engineers Districts.

2) Review Local Projections. Projections made by state or local agencies can be used in place of Federal projections when there is reason to believe that the local projections are more accurate by virtue of better localized or more up-to-date information. Where deviations from Federal projections are shown, the conditions that create those deviations should be well documented. Specifically, factors such as commitments by developers for large scale industrial, commercial, or residential developments; or the continuation of existing development trends, where there is strong reason to believe that land values, transportation costs, or other location advantages will cause continued development.

3) Identify New Information. Any locations of specific development commitments, where a developer or potential occupants have made a financial investment, should be considered as part of the base year conditions.

4) Adopt Population and Employment Projections. Population and employment projections should be determined for the study area to determine the approximate number of acres required for each of the major land use categories.

5) Establish Land Use Classifications. In general, land use categories will follow those established for existing conditions unless major changes in categories are anticipated. A major influx of new development may require the designation of new categories. Some land use categories may be consolidated if it is found that a more detailed breakdown makes little difference in the calculation of benefits.

6) Establish Land Use Requirements. The existing land use pattern should, in general, be assumed to continue in similar proportion to current patterns. Growth in demand for land can be determined by the projected change in population and employment. The change in the number of acres required for each type of land use should be determined by applying conversion factors to the projected changes in population and employment. For example, it might be assumed that residential development will occur at the same density as established residential development. If this is the case, the projected population increase can be divided by the current population per residential acre to determine the acreage requirement for new residential development.

7) Allocate Land Use Among Classifications. Land use allocation requires determining a set of requirements or attractiveness factors for each land use and matching these factors with the attributes of available land in the affected area, in and outside the floodplain. The desired attributes for each land use should be based on economic location theory, observation of past development trends in the area, and interviews with local developers and other business leaders. Once this initial research is completed, there are several models to allocate land use requirements among classifications.

One such model is the Alternative Land Use Forecasting (ALUF) program, developed by the Institute for Water Resources. (ALUF is not operational at the time of this publication.) The following describes how ALUF employs user-determined attractiveness factors for allocating land use.

Major attractiveness criteria include:

1. Access: distance to interstate highways and other major roads, distance to the central business district or other major commercial centers, distance to sources of supply and markets, and availability of public transportation.
2. Physical and land attributes: flood hazard, slope, drainage, ground cover, and soils.
3. Infrastructure: water supply, sewer system, electricity, and natural gas.
4. Local prerogatives: zoning, land use plan, transportation, and infrastructure plans.
5. Land prices.
6. Land ownership

Once these factors are identified for each of the potential land use categories, it is necessary to establish the importance of each of these variables and build that into the allocation equation either by giving each variable a weight or factoring it in as a constraint. The planner can then apply these factors to determine the predominant land use or the proportion of land use distribution for each designated planning area. Planning areas can be defined as grid cells of uniform sizes.

The ALUF program requires that the existing land use information be entered in a spatial data base of uniform grid sizes. The predominant land use is indicated for each grid cell. We might determine from our projections that residential, commercial, and industrial land use will be the predominant land use in say 900, 800, and 200 grid cells, respectively.

STEP THREE: ESTABLISH NEW FLOODPLAIN INVENTORY

Analysis of future benefits is based on the projected level of economic activity in the study area and its spatial distribution. The analysis entails reestablishing a projected inventory for each damage reach and floodzone so that depth-damage functions can be applied.

Once land use is established, there are three tasks in establishing the future floodplain structure inventory. These are: estimating the number and elevation of physical units, estimating the future value of those units, and determining the susceptibility of those units to flood damage. It can generally be assumed that land use patterns identified in Step Two will be the same, unless there is an impending development or recent change in the pattern of development that breaks with the existing land use.

AFFLUENCE FACTOR

Increases in residential content-to-structure value ratios are believed to increase with income over time. The affluence factor concerns the extent of increase in the content-to-structure value ratio over the 50

year horizon for projection of economic activity. The affluence factor is assumed to be in effect with or without a project.

Prevention of damages to future increases in content value of residential structures is a legitimate benefit when a flood control project protects residential development. (See page A21, ER 1105-2-40) These steps should be followed in calculating increases in residential content value over time:

1. Determine average content value of existing homes and compare them with average structural values. This is often in the 35-55% range.
2. Use OBERS regional growth rate for per capita income as the growth rate for increasing the value of residential contents in the future.
3. The future value of contents cannot exceed 75% of structural value nor can the growth period be projected beyond 50 years.
4. Assume damages (and benefits will increase at the same rate as content value.
5. Determine average annual benefits for protecting existing residential contents. Then, calculate the benefits for protecting projected increases in content value.

An example of benefit calculations using the affluence factor procedure is given in Chapter X on other benefits.

STEP FOUR: ESTABLISH NEW ELEVATION-FREQUENCY RELATIONSHIPS

Land use changes may cause major alterations in drainage characteristics, particularly surface runoff. Hydrologic changes should be projected up to the first 50 years of the project life, and will primarily be based on land use changes. It is important that hydrologic change be noted by time interval to reflect changes in the degree of protection over time.

Hydrologic changes are critical when determining the level of protection afforded by any particular measure. Consequently, conditions should not be presented as averages, but rather shown as incremental changes that are staggered over the period of analysis.

A. Calculate Land Use Changes Effect on Runoff

The rooftops, streets, and parking areas that come with urbanization can greatly reduce the amount of water that infiltrates into the ground. The additional runoff can be reduced by retention and diversion schemes. Otherwise, the increased runoff from urbanization will increase discharge at points downstream of the development.

B. Identify Other Physical Changes

Changes in the conveyance system that carries stormwater runoff can also affect elevation-frequency relationships. Cleared and otherwise smooth channels convey water more quickly and sustain fewer runoff losses than channels with vegetation and other obstructions. Storm sewers also cause more rapid conveyance, unless temporary storage is provided.

C. Re-do Hydrologic Analysis

The total amount of discharge for a given frequency of storms can be estimated by calculating the combined effects of the hydrographs for each sub-basin. The rainfall/frequency relationship is held constant. The new hydrograph is computed for each sub-basin by use of a simulation model that calculates and applies new runoff coefficients.

D. Review Hydraulic Analysis

For without-project conditions, hydraulic changes will be limited to any impending physical change, such as a bridge replacement, or anticipated long-term physical process that would affect the geometry of the channel and consequently affect the stage-discharge relationship.

E. Calculate New Damage-Frequency Relationships

1) Update of Land Use Information by Step

2) Apply New Elevation-Frequency Relationship

STEP FIVE: CALCULATE EQUIVALENT ANNUAL DAMAGES

Equivalent annual damages are the discounted values of damages after the mandated interest rate has been applied. While projections are limited to 50 years, equivalent annual damages are based on the entire project life, up to 100 years.

The elevation-damage relationship is calculated by the same procedure illustrated in Step 7 of Chapter V. Elevation-damage curves change as a result of work done in the previous four steps.

Equivalent annual damages are calculated using established procedures similar to calculating average annual damages as illustrated in Chapter V.

An important difference between expected annual damages and equivalent annual damages is discounting. The effect of discounting is to lower the average annual expected value of future flood damages. For example, the equivalent value of flood damages seven years into the future might be worth 50 percent of the same damages if they were to occur this year.

Figure VI-1 shows some of the possible growth trends that could occur. Between existing and base year conditions, damages could increase, remain constant, or decline. Evaluation of the most probable future condition will determine which growth trend occurs. However, it is important to emphasize that existing conditions must first be clearly defined. Without knowing "what is," it is unlikely that "what will be" can be properly defined. Curve II represents constant conditions over the entire study period. Damages computed for existing conditions, therefore, represent annual damages over the entire period considered. If, on the other hand, conditions change significantly between existing and base year conditions, as suggested by Curve I or Curve IV, existing EAD must be adjusted to establish a new base year estimate. Generally, however, because of the relatively short period involved, damages usually remain unchanged from existing to base year condition. Let us assume that, because of changed economic conditions, Curve III represents the future growth path of damages. This curve is isolated and shown in Figure VI-2. Damage estimates represented by this curve are based on future economic and hydrologic changes, generally categorized as future urbanization. These future values are discounted and annualized in accordance with procedures in Chapter XI on "Discounting Procedures."

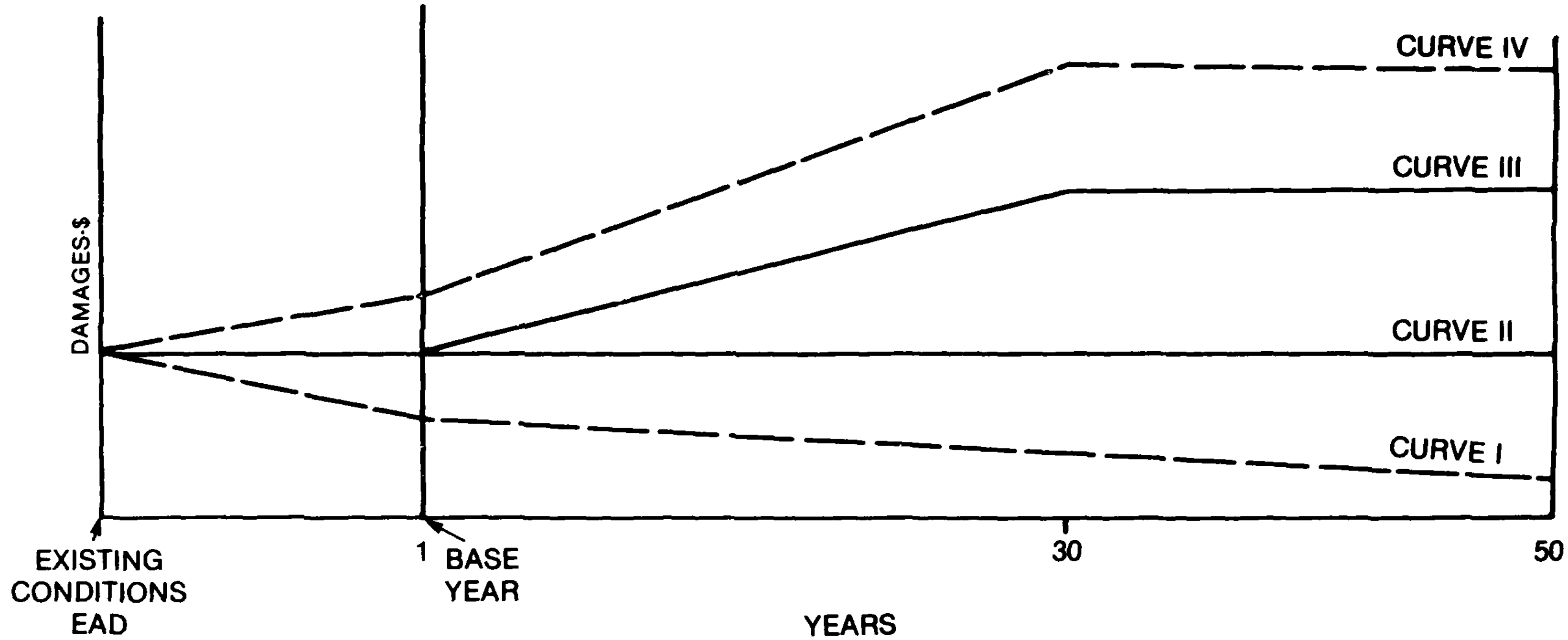


FIGURE VI-1 EXPECTED ANNUAL DAMAGES WITH ALTERNATIVE GROWTH TRENDS

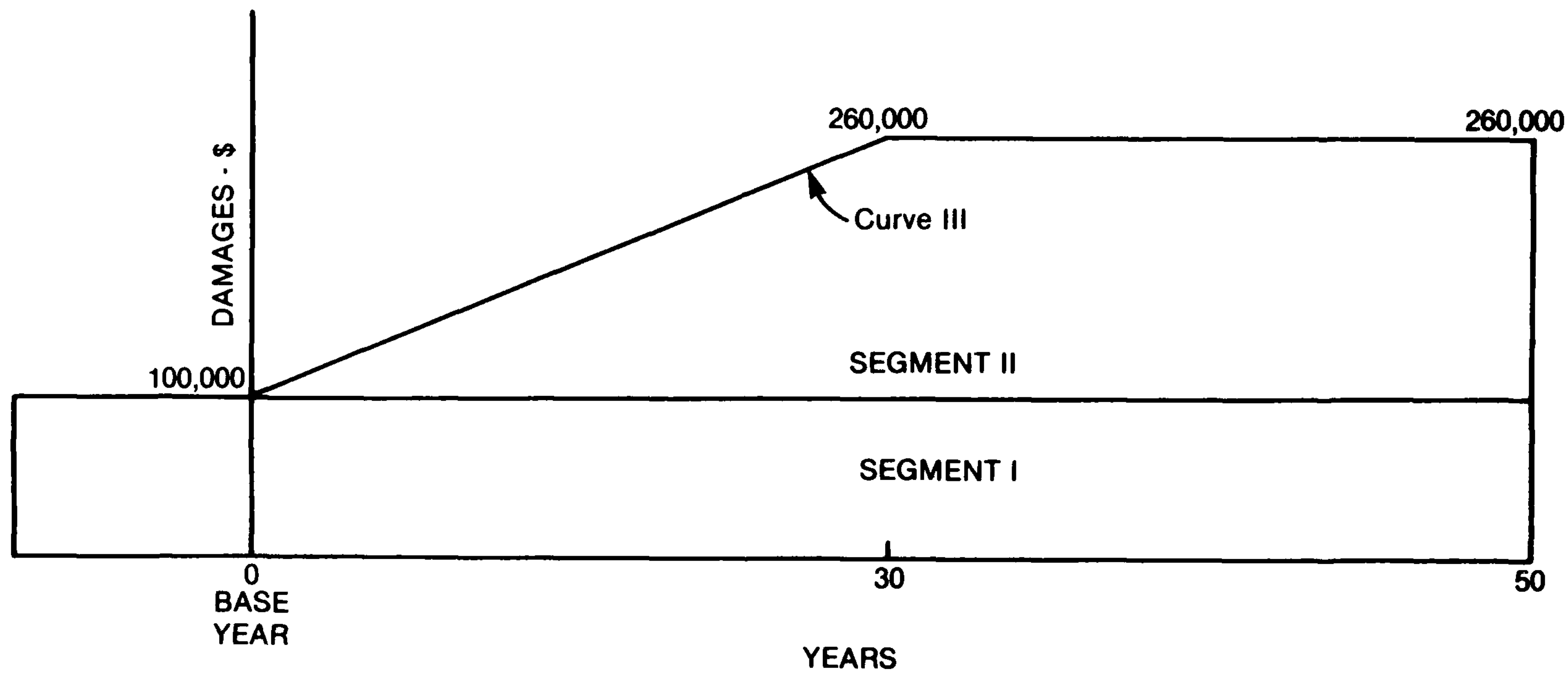


FIGURE VI-2 EXPECTED ANNUAL DAMAGES

CHAPTER VII

CALCULATION OF NON-PHYSICAL COSTS

OVERVIEW OF THE PROCESS

This chapter describes the types of costs that are incurred by floodplain occupants beyond the physical flood losses described in Chapters V and VI. There are two types of non-physical costs: 1) costs, such as income loss, emergency costs, traffic rerouting, and temporary relocation, that are incurred only in the event of a flood or when flooding look imminent enough to warrant emergency action; and 2) costs that are incurred because of the flood potential regardless of any particular flood event.

PROBLEMS IN ESTIMATING NON-PHYSICAL COSTS

The magnitude of non-physical costs are not well documented. There are few, if any, commonly accepted generalized non-physical costs functions similar to what there is structure and content damage. Unless any generalized relationships is available, these costs should be estimated from specific independent data, and not computed as a percentage of physical damage. Accurate estimation of these costs requires compilation of information from a number of public agencies, service organizations, businesses, and individuals. Estimation of non-physical costs also requires the use of "shadow prices" or proxies for the uncompensated time flood victims and volunteers spend in damage prevention

and post-flood recovery periods. Because of these problems, non-physical costs often receive limited attention in benefit calculation, and the alleviation of these costs does not generally constitute a large portion of the average annual benefits. The level of detail spent on estimating these costs should depend on whether there is good reason to believe these costs are significant and whether there is potential of significantly reducing these costs.

There are six categories of non-physical costs identified in P & G. These are income losses, emergency costs, floodproofing costs, the administrative costs of flood insurance, restoration of land market values, and the modified use of floodplain property. The definition of these categories, the application of these benefits to NED benefit calculation, and formulas for their calculation are all given below:

INCOME LOSS

Income losses are reductions in the national income when flooding or the threat of flooding halts production or delivery of goods and services. National losses occur 1) when the production or delivery of these goods and services are not recuperated by postponing the activity or transferring it to another location, or, 2) when there are additional costs caused by delay or transfer of the activity.

Income losses are incurred by businesses and labor as a result of flood induced shut-down in the production and delivery of goods and services. These losses can occur at any time during three periods: 1) flood warning, when business operations shut down and effort concentrates

on damage prevention and evacuation; 2) flood inundation, when flood fighting and evacuation continues; and, 3) cleanup and restoration, when there may be a phasing in of normal activity. Even the threat of flooding can cause shut down of business operations for extended periods along large river basins. Inundation can vary from several hours to over a week, depending on the sources of flooding.

Income losses may occur directly to the business or institution being flooded or losses may occur indirectly when roads are closed and public utilities are cut off. Business losses can also occur from the spoilage of perishable commodities and when their processing or distribution are interrupted by flooding. Income losses also include any additional transportation or production costs that occur from transferring production from one area to another.

There are no general guidelines as to what constitutes non-recoverable income losses. That determination would have to be made by questionnaires and post-flood surveys of the directly affected businesses and other firms that supply identical or easily substitutable goods and services in the same market area. It is likely that non-recoverable business losses mostly follow unique patterns and would therefore require individual attention.

Businesses where losses would be expected to be non-recoverable include:

1) public utilities, including water supply, electricity, natural gas, and telephone;

2) those where delays in delivery or processing cause spoilage of perishable items, such as meat, dairy products, fruits and vegetables, and baked goods.

3) businesses that produce unique products or businesses whose competitors are at full production;

4) newspapers, radio, and television stations which provide the only sources of local or national information;

The likely production loss that would occur from the use of company resources for repair and clean up of damaged property should not be counted if it has already been used to estimate the physical damage to structure and contents.

The amount of income loss, as an NED consideration, is measured by the value added from the activity at the particular firm in question. "Value-added" refers to the increase in value to a final product or service solely from input by the facility in question. Only factors that provide real increases in the value of the output should be considered. For example, the labor and machine processing that goes into an industrial product adds to the real value of a product. The taxes paid by the facility do not directly add to the real value of the product, although they do add to the final price.

The procedure for computing income-loss for any given business is given by the following equation:

$$L = N * V * \frac{D}{H}$$

where L = the income loss for an individual business
N = the number of employees
V = the annual value-added by the business per employee
D = the duration in operating hours that a business is closed, and
H = the number of hours the business operates in one calendar year.

Most of the variables in this equation are self-explanatory. The data for most of these variables are readily available. The value-added for the business may be estimated by multiplying the number of employees in the business by the average value added per worker for that industry. The formula given above is adapted from Kates' Industrial Flood Loss in the Lehigh Valley, p. 56.

Value-added statistics can be obtained from the Regional Analysis Division, Bureau of Economic Analysis (BEA), U.S. Commerce Department. The BEA has compiled value-added statistics for each state by two-digit SIC codes equivalent, available on microcomputer diskettes and published by one-digit industries in the BEA publication, Experimental Estimates of Gross State Product by Industry, Staff Paper #42. Both the microcomputer data and published information are 1972 data. Annual estimated value-added data are available by the equivalent of 4-digit SIC codes on BEA's National Regional Impact Evaluation System (NRIES) II. These annual data are compiled by somewhat less rigorous means.

EMERGENCY COSTS

Emergency costs include: 1) efforts taken to monitor and forecast flood problems; 2) actions taken by police, fire, and the National Guard to warn and evacuate floodplain occupants, to direct traffic, and to maintain law and order during a flood; 3) flood fighting efforts, such as sandbagging and building closures, taken to reduce flood damages; 4) costs of efforts, such as emergency shelters and provision of money, food, and clothing, offered to relieve the financial situation experienced by flood victims during and after a flood emergency; 5) evacuation costs for floodplain residents; and, 6) the administrative costs for public agencies and private relief agencies in delivering emergency services.

Emergency costs generally include only the variable costs that would be incurred at the time of a flood event. The fixed costs of emergency programs, such as maintaining the administrative staff and equipment needed in typical daily operation should be considered only if there is a reasonable possibility that these costs could be reduced by a project. For example, the number of people and equipment necessary for maintaining a flood warning system might be reduced with a reservoir or a channel project. Monitoring rain and stream gages might be eliminated. Less detail might be necessary for maintaining the flood forecast program.

TRAFFIC REROUTING

Flooding can temporarily impede traffic by covering roads and bridges. Even the threat of flooding and concern for public safety may make it necessary to close roads and detour traffic. Bridge and road

damage may cause detours for several months until repairs can be made. The costs of traffic disruption include 1) the additional operating cost for each vehicle, including depreciation, maintenance, and gasoline per mile of detour; and, 2) the traffic delay costs per passenger.

To determine traffic operating cost, it is first necessary to determine the frequency, depth, and duration of flooding along major stretches of road that are subject to flooding. In order to concentrate on areas where the most significant benefits might occur, it is necessary to focus on portions of roads where there would be considerable traffic rerouting for long periods of time.

Beyond the inundation mapping, there are eight tasks necessary to determine the operating costs of traffic rerouting:

1) The amount of time that a particular stretch of road would be impassable is estimated.
2) Local traffic counts are used to determine the extent of daily and seasonal (if traffic is very seasonal, a relationship could be established with the seasonal probability of flooding) traffic crossing bridges and major thoroughfares affected by the flooding. Separate counts are obtained for automobiles and trucks.
3) The number of miles are determined for the original route.
4) The number of miles are determined for the best alternative route. Highway departments will often have detour plans that can be used for making these estimates.
5) The additional miles per vehicle are determined.

6) The total amount of additional mileage is determined for all automobile and truck traffic.

7) Estimates of the average vehicle operating expense are obtained from the closest office of the American Automobile Association. The Private Truck Council of America and the Chilton Company publish the Cost Index Survey for Private Trucks. A good reference was the U.S. Federal Highway Administration, Cost of Owning and Operating Automobiles and Vans, last published in 1984. The average operating cost statistics are multiplied by the total mileage requirements for automobiles and trucks to obtain the total additional operating cost for each type of vehicle.

8) The total additional operating costs for automobiles and trucks are added together to obtain the operating cost by frequency of event.

An example of these procedures is given below in Table VIII-1:

Table VII-1

ADDITIONAL OPERATING COSTS ASSOCIATED WITH INUNDATED ROADWAY (100-YEAR EVENT)

Step One: Flood duration above 1 foot	100 hrs.
Step Two: Average traffic count for period of flooding	
Automobiles	70,000
Trucks	15,000
Step Three: Number of Miles for the Original Route	25
Step Four: Alternative Route Mileage	30
Step Five: Additional Mileage per Vehicle	5
Step Six: Total Additional Auto Mileage	350,000
Total Additional Truck Mileage	75,000
Step Seven: Total Additional Operating Costs	
Automobiles (350,000 * $.30/mile)	$105,000
Trucks (75,000 * $.50/mile)	$ 37,500
Step Eight: Total Additional Operating Costs for a 100-year event	$142,000

The second portion of traffic rerouting is traffic delay costs. This cost accounts for the additional time spent by individuals forced to take the detours due to road closings. Since time is usually more valuable than the average vehicle operating costs in the same period, traffic delay costs can be expected to be higher than traffic operating costs.

The procedures for calculating traffic delay costs are as follows:

1) Determine the total number of miles for the original route and for the detour route for automobiles and trucks. This can be obtained from steps 2, 3, and 4 of the traffic operating costs procedures.
2) Determine the amount of time required on the original route for cars and trucks. The average speed under all times and conditions

weighted by the amount of traffic should be multiplied by the number of detour miles.

3) Determine the amount of time required on the alternative route for automobiles and trucks. The weighted average speed for the alternative route under all times and conditions should be multiplied by the number of detour miles.

4) The additional travel time is computed by subtracting the original travel time from the rerouted travel time for both automobiles and trucks.

5) Determine the approximate average number of passengers per vehicle by contacting the state department of transportation or the local public works department.

6) Guidelines on assessing cost of travel for automobile drivers and passengers are found in Appendix A in P & G of Section Seven on the travel cost method for computing recreation benefits. It is recommended that the costs of travel time for adults be assessed at one-third the average local wage for adults and children at one-twelfth the average wage rate.

7) We can assume that truck drivers are mostly operating their vehicles in the course of work. Therefore, it is reasonable to use the average local wage for truck drivers to determine the delay costs for trucks.

8) Automobile and truck delay costs are added together to determine the total cost per event.

An example of traffic delay costs taken from the Passaic River Study is given below in Table VII-2:

TABLE VII-2

TOTAL TRAVEL COST ASSOCIATED WITH INUNDATED ROADWAY (100-year Event)

Step One: Original mileage for automobiles
25 * 70,000 = 1,750,000 miles
Original mileage for trucks
25 * 15,000 = 375,000 miles
Detour mileage for automobiles
30 * 70,000 = 2,100,000 miles
Detour mileage for trucks
30 * 15,000 = 450,000 miles

Step Two: Original travel time for automobiles
1,750,500/45 mph = 39,000 hours
Original travel time for trucks
375,000/45 mph = 8,333 hours

Step Three: Detour travel time for automobiles
2,100,000/10 mph = 210,000 hours
Detour travel time for trucks
450,000/10 mph = 45,000 hours

Step Four: Additional travel time for automobiles
(210,000 - 39,000) = 171,000 hours
Additional travel time for trucks
45,000 - 8,333) = 36,667 hours

Step Five: Total delay costs
Automobiles (171,111 * $2.80/person hour
* 1.25 adults per vehicle) = $598,500
(171,111 * $0.70/person hour
* .6 children per vehicle) = $ 71,820

Trucks (36,667 * $12/person hour) = $ 440,004

Step Six: Total Delay Costs to All Vehicles = $1,110,324
(Some numbers in this example have been rounded to the nearest ten.)

Children and adult automobile delay costs are one-third and one-twelfth the average local wage, respectively, as discussed under step 6, above. Twelve dollars represents the average local wage for truck drivers.

FLOODPROOFING COSTS

The costs of permanent or dry flood proofing measures taken by individuals to protect their property and to meet the National Flood Insurance Program requirements can be eliminated by structural protection measures and permanent relocation.

Floodproofing costs are incurred from the adoption of permanent features, known as dry floodproofing and the adoption of temporary measures during periods of flooding, known as wet flood proofing.

Floodproofing costs should be thought of as applying to individual units, as distinct from emergency preparedness activities that apply mostly to outside property. These costs can be expected to vary a great deal, and they cannot be properly estimated without extensive survey of the study area. The estimated costs should include the expenses for all material and labor, with labor valued at the average area rate for custodial services. The effects of these measures are considered in depth-damage relationships.

ADMINISTRATIVE COSTS OF FLOOD INSURANCE

The administrative costs of flood insurance are real costs, whereas the money paid in claims are transfers between individuals and businesses, and between the same individuals within the same time period. Estimates of the average administrative costs per policy are made every year and published in the "Fiscal Year Reference Handbook, as an Engineering Circular (EC). For Fiscal Year 1987, administrative flood insurance costs

were estimated to be $85 per policy. These costs are estimated to be the same for residential and business properties. The percentage of properties with flood insurance policies can be determined from the records of the regional flood insurance office.

The benefits of the reduction in flood insurance costs apply to properties that would no longer be in the 100-year floodplain under with-project conditions. The benefits are determined by multiplying the number of affected properties by the approximate proportion with flood insurance coverage, times the average annual administrative costs per policy.

TEMPORARY RELOCATION AND REOCCUPATION COSTS

Temporary relocation includes the additional living expenses incurred by floodplain residents who are forced to find temporary housing during and after a flood. Homes may be made uninhabitable due to: 1) extended periods of inundation; 2) structural damage that is too severe to live with, as when critical parts of the structure, such as plumbing, heating, and electrical systems are ruined or inoperative, or when silt and debris is widespread throughout the structure; 3) large deposits of silt and debris; and, 4) cutoff of transportation routes and utility services.

Temporary relocation costs include: 1) the costs of motel rooms or apartment rentals; 2) the extent that costs of restaurant or prepared food exceed ordinary grocery costs; 3) additional costs of commuting to work and school; and, 4) the opportunity costs of the time spent in making household repairs, contracting for repairs, and purchasing new furnishings

and personal effects. The net difference in utility expenses should also be considered.

Whether or not individuals are forced to temporarily relocate because of flooding, they will still incur the expenditure of many hours in contracting, supervising and inspecting repairs made on their home, contracting for repair and replacing household furnishing, and filling out casualty loss forms for flood insurance, income tax deductions, and other disaster assistance. These costs should be determined by interviewing a sample of flood victims who have experienced varying depths of flooding.

Relocation costs apply primarily to high levels of inundation and when there are flood durations of one day or longer.

MODIFIED USE OF FLOOD-PRONE PROPERTY

The threat of flooding will often cause occupants not to use areas of their buildings that are subject to the most serious flood threat or cause a less valuable or inefficient use of the property. Arrangements of contents, although it may be considered inconvenient, is not a major economic loss. For benefits to be considered for this category, there should be evidence of a substantial number of rooms or properties otherwise not in full use. This category closely parallels benefits for more intense use of floodplain business property, described in Chapter X, and the affluence factor for residential property described in Chapter VI. The distinction is that intensification benefits and affluence factor include the acquisition and use of new and more valuable contents, while

modified use refers strictly to a change in the actual use of a portion of the structure.

RESTORATION OF LAND MARKET VALUES

Restoration of land market values is a seldom used, but legitimate benefit category described in paragraph 2.4.13d of P & G. This benefit category is intended to capture benefits that otherwise might be considered intangible. This might include the psychological trauma and inconvenience of flooding which would be perceived in the real estate market. These are costs faced by the property owner which are over and above the costs of flood insurance premiums, uninsured flood losses, and temporary relocation. P & G states that this benefit category is applicable to building as well as land, but since land usually suffers little physical damage in a flood, it may be easier to make the case that the lowering of land values are over and above the internalized physical losses in the form of insurance premiums and uninsured losses.

To determine the extent of these costs, it is necessary to compare real estate values in the floodplain with either comparable properties outside the floodplain or determine the effects that similar flood protection projects may have had on land values. From that it is necessary to project the increase in values that flood protection might bring to the project area.

A sample calculation of the restoration of land market values benefits is given below in Table VII-3:

TABLE VII-3
RESTORATION OF LAND MARKET VALUES

Value of Restored Land	$20,000,000
Value of Land in Present Condition	$16,000,000
Increase in Value	$ 4,000,000
Reduction in Flood Insurance Premiums, Uninsured Physical Damages, and Temporary Relocation	$ 3,000,000
Total Benefit	$ 1,000,000
Average Annual Benefit	$ 88,770

These benefits are computed for a 100-year life at 8 7/8% discount rate.

The evaluator should be cautioned that the specific concern here should be for long term land values. The market value of property can be expected to change significantly with the amount of time since the most recent damaging flood. The evaluator should be concerned with long-term land values that would average out the changes of land values for flooding and non-flooding years.

If the land is currently undeveloped. It would be easier to measure the enhanced value as a location benefit. If the land in question is part of developed property, it should be clearly demonstrated that there is no double-counting what may already be claimed under physical inundation reduction benefits.

CHAPTER VIII
CALCULATION OF INUNDATION REDUCTION BENEFITS FOR STRUCTURAL MEASURES

OVERVIEW OF THE PROCESS

Various floodplain management options are available to reduce flood damages to existing and future occupants. The options can be divided into two main categories, structural and nonstructural. Structural flood damage reduction measures are defined as those measures that modify the height, amount, duration, frequency or extent of flooding in an area. Similarly, nonstructural measures are defined as measures that modify the response to or susceptibility of floodplain property to flood damage rather than changing the characteristics of the flood itself. Thus, a project to keep river flows within banks would be structural, while removing damageable property from the natural floodplain would be nonstructural. Building a levee around a town would be structural, but building a floodwall around an individual building would be nonstructural.

While the delineation between structural and nonstructural measures may seem simple, some measures have characteristics of both types. Projects are often formulated with combinations of measures, so that they cannot be easily classified as one or the other. Because of cost sharing differences between the two types of measures, project components must be accurately classified so that appropriate cost sharing can be devised. This determination must be made for each project. Difficult cases often encountered include a floodwall that protects a small number of buildings and plans that combine dikes or channel improvements with warning systems or floodplain regulations. Usually these projects can be classified by

looking at the total plan and the measure's interaction with related flood control plans.

There are many types of structural measures, including traditional Corps projects like dams, channelization, levees, and more recent proposals like movable barriers and diversion tunnels. Each measure can be designed to provide varying degrees of protection and geographic scope. Measures may be combined or supplemented with non-structural solutions.

IMPOUNDMENTS: WET AND DRY RESERVOIRS

The first type of structural measure is impoundments that hold floodwaters during storm periods and gradually release the water during periods of lower flow. This serves to reduce the frequency of various flows, reducing flood heights and decreasing flood damage. The storage volume could be part of a multi-purpose reservoir allocated to flood control, or a single purpose flood control reservoir either having a small permanent pool or acting as a dry dam. The magnitude of flood reduction depends on the storage volume available, the amount and timing of the runoff, and distance to the damage area. Flood stages are determined by calculating frequency-discharges for the with- and without-project conditions and converting the discharge to flood stages using a rating curve or a hydraulic model. The dam would have little effect on the downstream hydraulics, but it would alter the frequency with which certain flood flows would be expected to recur. Benefits may be computed by comparing damages from the stage-damage relationship, also unchanged, for each condition. Generally, flood control dams produce lower downstream

stages but for a longer duration. This would normally result in less damage for a given frequency flood (a lower frequency-damage curve) and a net beneficial effect. In some agricultural or forestry situations, the duration of flooding is more disruptive than the depth (especially when the depth has been regulated), giving negative benefits (or costs) to the evaluation of the project. These costs should be recognized and could play a significant role in the future operation of the dam. Figure VIII-1 shows how various reservoir designs affect damage frequency relationships.

In should be recognized in evaluating multi-purpose reservoirs, that flood control maybe only one of many project benefits which must compete for the available storage. Other benefit categories such as water supply, hydropower, water quality releases, recreation, and fish and wildlife enhancement may be adversely impacted by the flood control storage. In some areas at certain times, flood control storage is the only purpose served. The operating system for a reservoir is very important in determining the after-project condition. A single size reservoir at a particular site may have several plan formulations based on the storage allocated to competing uses. The economist or study team must accurately weigh the beneficial and adverse impacts to each category from a particular reservoir operation system.

A dry dam is a much simpler operating system, having only one primary purpose (flood control, but possibly including some outdoor recreation) whose benefits may be calculated using straight-forward with and

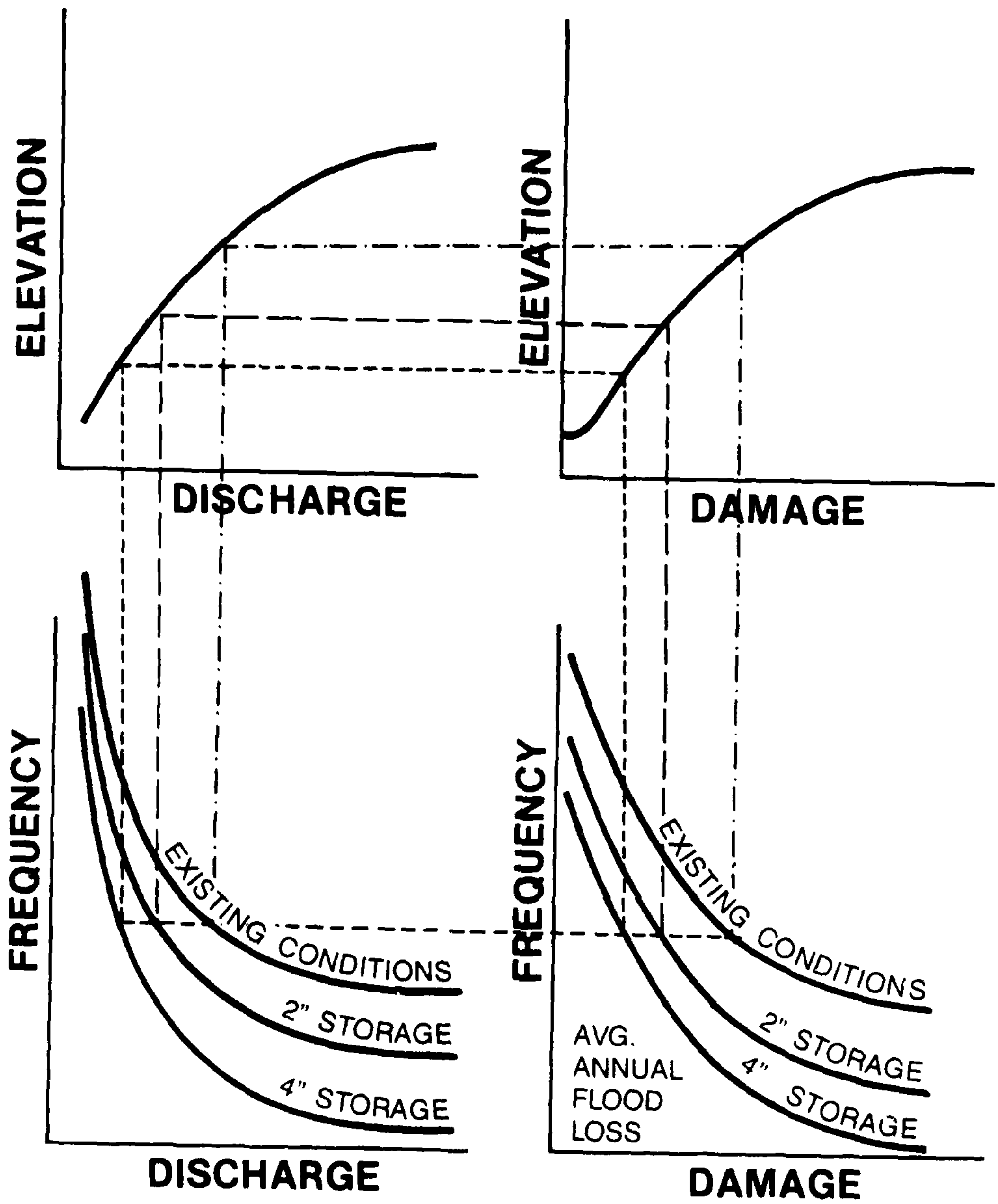


FIGURE VIII-1 ECONOMIC AND HYDROLOGIC EFFECTS OF RESERVOIRS

without-project conditions. Dry dams are more difficult to justify economically (less benefit categories) and are often less popular with local sponsors. They require large land areas and relocations much like a lake, but would not have the same water quality or evaporation problems. In most urban areas, a multi-purpose project would be much more feasible because of the high demand for additional project outputs, such as water supply and water-based recreation. Since the incremental cost for these features is usually less than the incremental benefits, they improve the economics of the overall project.

An example of an impoundment analysis is a dam site which can be developed to provide 2, 4, or 6 inches of storm runoff storage for all of the basin upstream of the reservoir. The following table shows the beneficial flood control effects of each option.

Table VIII-1

Damage Prevented by Reservoirs for a One Percent Flood

Plan of Development	F.C. Acre-ft Storage	Discharge	One Percent Flood Stage	One Percent Flood Damages	One Percent Flood Benefits
Natural condition	0	50,000	30.0	2,000,000	0
2" Flood cont	6,000	44,000	27.0	1,200,000	800,000
4" Flood cont	12,000	37,000	23.0	600,000	1,400,000
6" Flood cont	18,000	29,000	18.0	200,000	1,800,000

BARRIERS: LEVEES AND FLOODWALLS

A second type of structural measure is barriers to protect the occupants of the floodplain from inundation. The best known of these are the extensive levee systems along the Mississippi River. Also included would be dikes and floodwalls, floodgates, wind-tide barriers, and coastal berm-and-dune projects. These measures raise the beginning damage level to the top of the structure design height, including a freeboard allowance, and are then subject to complete or near-complete failure. These barriers affect the extent of flooding and may or may not change the flood height or peak discharge volume. Hydrologic and hydraulic (H & H) analyses must be done to determine if lost storage volumes and flow areas are significant enough to change frequency-discharges or flood heights. In the event that a levee is overtopped, damages could be higher than if no levee were built because of a false sense of security, induced development, and longer flooding durations. The local flood warning and evacuation plans are essential with low-level levees and should be planned before such a project is recommended.

Barriers which prevent the entry of water also prevent the exit of water and may require pumps and/or storage areas to reduce damage from interior drainage. In these cases, economic analyses should include residual damages from interior ponding and operation, and maintenance and replacement costs for pumps and flood gates. Benefits for the levee are calculated by modifying the stage-damage curves to show no damages until the level of protection is exceeded. Dikes are usually designed to include an additional height called freeboard to account for risk,

hydrologic imprecision, wave action, and uncertainties. A flood reaching the design stage of the dike would not cause immediate failure because of this freeboard allowance. Present guidance allows for benefits to be claimed in this freeboard area as one-half the total benefits in the area between the design flow and the maximum flow that can be safely passed. In many cases the benefits from this freeboard may be significant, especially when a large freeboard allowance is required. Figure VIII-2 shows the effects of various levee designs on the elevation-damage relationship.

An example of a dike plan is an urban levee providing nominal levels of protection and including 3 feet of freeboard allowance. Table VIII-2 shows the beneficial effects of various levee heights.

Table VIII-2

Average Annual Benefits for Levees

Plan of Protection	Protection Stage	Stage at Top of Levee	Frequency at Top of Levee	Avg. Annual Benefits for Design	Avg. Annual Benefits for Freeboard	Total Avg. Annual Benefits
3.33% (30-yr) levee	9.0	12.0	1%	600,000	200,000	800,000
1% (100-yr) levee	12.0	15.0	SPF	1,000,000	500,000	1,500,000
SPF levee	15.0	18.0	>SPF	2,000,000	200,000	2,200,000

Coastal berm-and-dune projects do not provide complete flood protection, because they can often be surrounded by water and are subject to seepage. They may reduce flood stages, erosion, and wave action. Flood control benefits may be claimed for flood stage reduction, height of

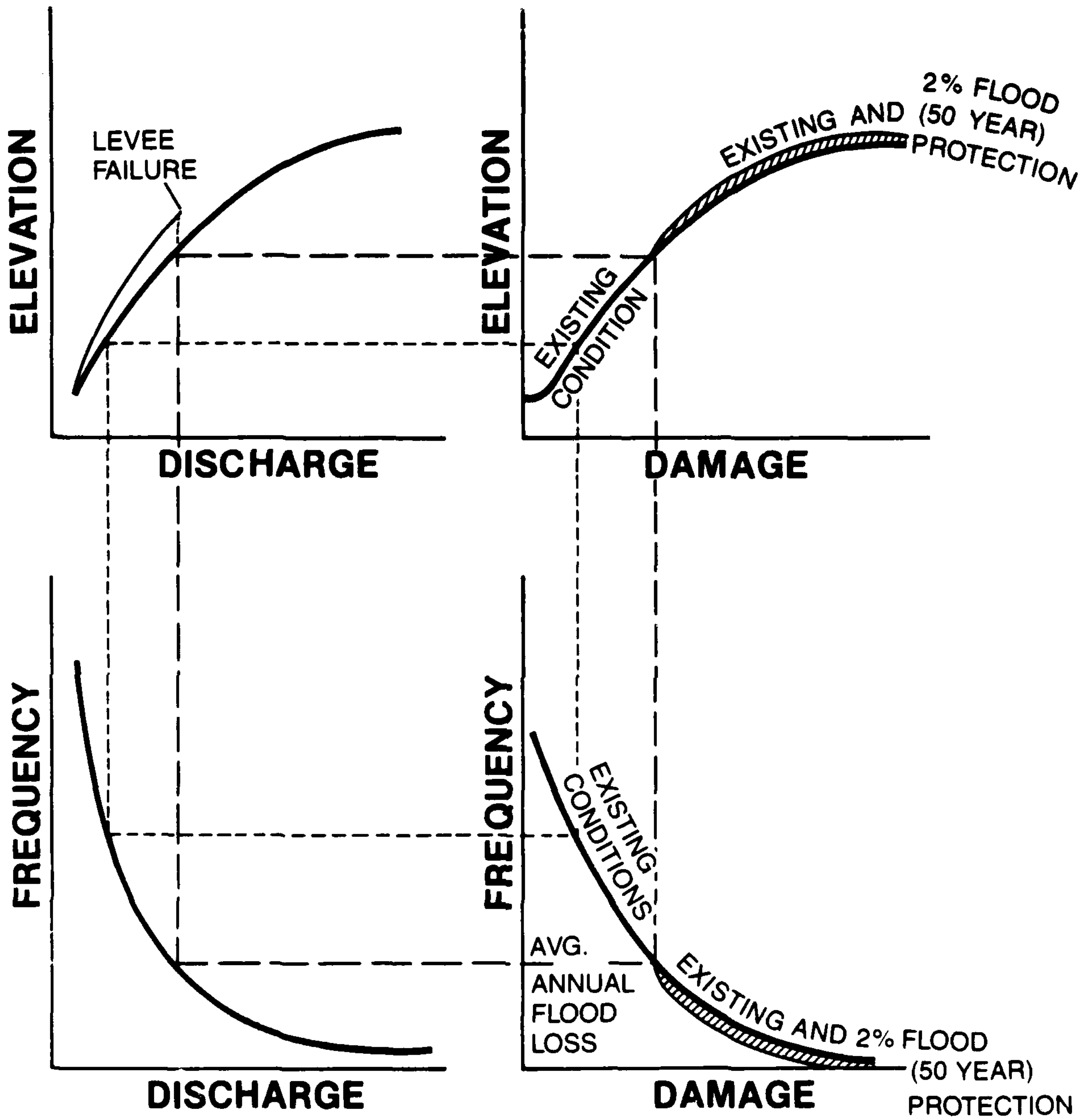


FIGURE VIII-2 ECONOMIC AND HYDROLOGIC EFFECTS OF LEVEES

wave run above the still water level, and damages from wave velocity protected against by the berm-and dune. Berm-and-dune projects usually receive most of their benefits from recreation and erosion protection, rather than flood control. They require periodic renourishment to maintain their effectiveness and may give a false sense of flood protection to the unwary.

Coastal barriers to protect against wind-tide flooding may be constructed across an estuary either with a gated opening or with an open navigation channel. An ungated opening would allow some floodwaters to enter but would give a decrease in stages, becoming more pronounced farther upstream from the opening. Benefits are calculated as the pre- and post-project stages compared to the same stage-damage curves. Residual damages should be calculated for ponded runoff with a gated opening and routed flows for an ungated opening. The community's ability to operate the gates (which may include stop log structures) and the barrier's effect on harbor-of-refuge navigation should be determined.

CHANNEL WORK

A third type of structural measure is an increase in the hydraulic capacity of the stream channel to decrease flood stages for the same rate of discharge. This increase in flow area may come from widening and/or deepening the channel, cutting a bench channel at a specified height above the stream bottom, or providing a diversion channel or cut-off. In some cases the channel walls may be modified to decrease friction and improve flow, such as paved or concrete channels. Clearing and snagging or

removal of vegetation or aquatic weeds may also be done to improve capacity and decrease flood stages. The new channel capacity is often defined in the frequency-discharge it can contain. Figure VIII-3 shows how different channel designs affect the elevation-discharge relationship.

These measures to improve hydraulic capacity may lessen floodplain storage, increase velocity, and decrease peaking times which may result in higher downstream stages. Benefits may be claimed as the with and without-project stage-frequency compared to the stage-damage function. Any area of negative impact should be included. Also, future damage predictions should take into account any decrease in hydraulic efficiency over time, the cost of a preventive operation and maintenance system, and future growth in floodplain occupancy. Regulatory floodways should be established to prevent encroachment into the improved floodplain and maintain hydraulic integrity.

An example of a channel improvement project with 50, 80 and 120 feet bottom widths is shown below. The following table shows the beneficial effects of each plan:

Table VIII-3

Average Annual Benefits for Channel Work

Plan of Channel	Bankful Capacity	Beginning Dam Frequency	Avg. Annual Damages	Avg. Annual Benefits
Natural	5,000 cfs	50% (2-yr)	2,000,000	0
50-ft BW	10,000 cfs	6.67% (15-yr)	1,200,000	800,000
80-ft BW	20,000 cfs	1.25% (80-yr)	500,000	1,500,000
120-ft BW	30,000 cfs	.5% (200-yr)	200,000	1,800,000

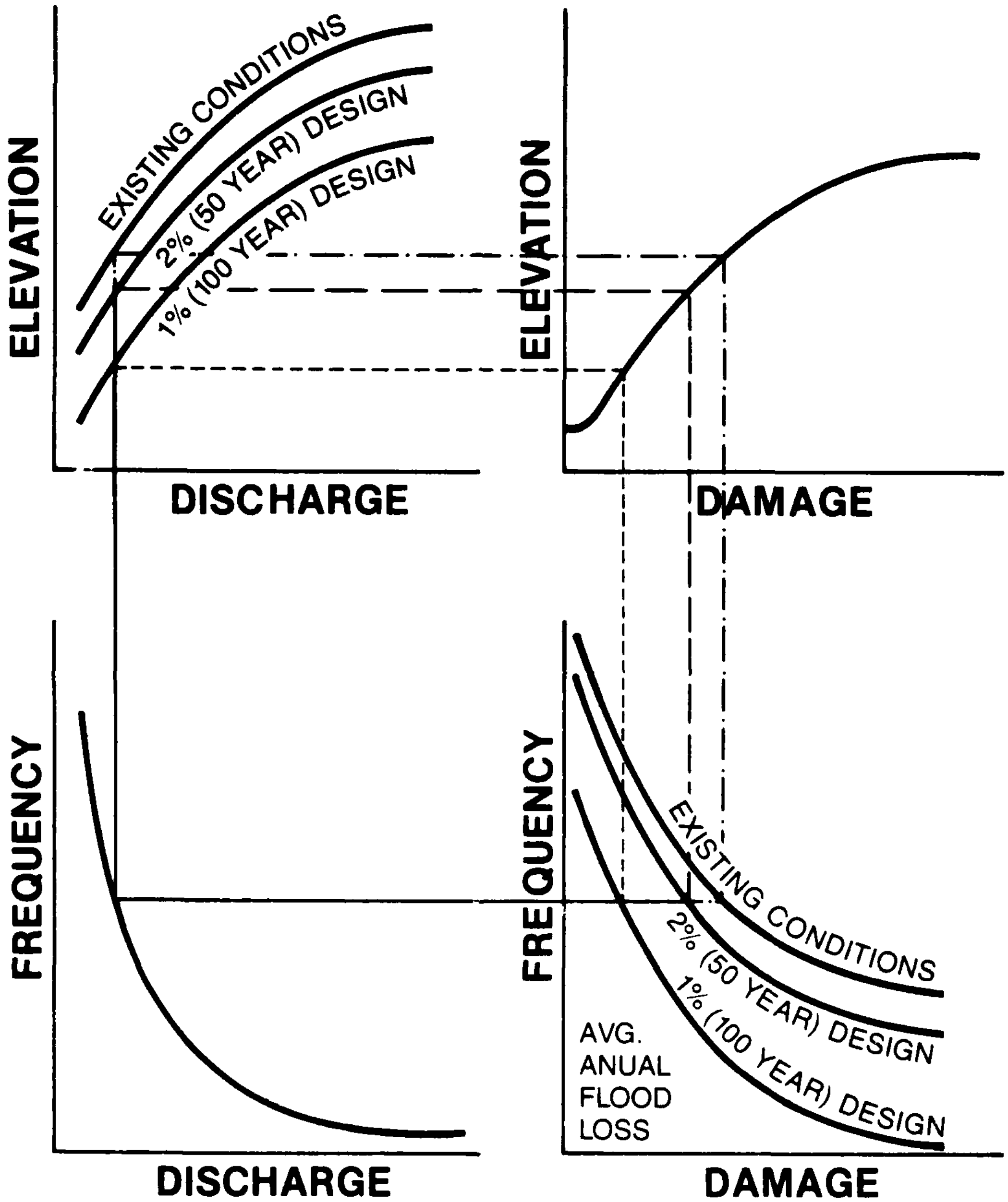


FIGURE VIII-3 ECONOMIC AND HYDROLOGIC EFFECTS OF CHANNEL PROJECTS

IMPEDIMENT REMOVAL

A fourth type of structural measure would be the removal or modification of any impediments to flow, such as dams, restrictive bridges, piles, piers, or rock outcroppings to improve flow and decrease stages. Evaluation of this measure would be similar to channel improvement and should account for any decrease in water surface elevation for any given frequency of flooding. In bridge replacements, highway betterments may be subtracted from the project cost in the economic analysis. Improvements to navigation should also be considered a benefit.

COMBINATIONS OF MEASURES

The larger flood control studies often analyze combinations of structural measures to produce the desired improvements. Plans are formulated with interrelated measures of various sizes and protection levels to maximize net NED benefits. For example, since land is scarce in urban areas and floodwalls or levees may be difficult to locate and unappealing, floodwalls, levees and channel improvements are often combined to yield higher levels of protection than would be available separately. In some cases, measures to modify the discharge-frequency, stage-discharge response, and stage-damage results are all included in one comprehensive plan. The effects of each of the plan's components must be determined individually and collectively during the economic analysis.

Benefits from a combination of measures are not additive, but must be analyzed to determine the combined effect.

OTHER CONCERNS

The interaction between the economic and hydrologic aspects of urban flood control planning is crucial to the development of workable plans that will function efficiently. These two study aspects should be matched for level of detail, timing of results, and data compatibility. Stage-frequency curves should be developed for the existing natural and improved conditions, and at least the base year condition, and 25th and 50th project year conditions.

Many economic flood damage programs are now available which compute damages and benefits directly from hydrologic results, usually HEC-2 flood profiles. They allow accurate computation of flood damages without requiring adjustments to index points. This interaction is placing greater demands on the economist to understand hydrologic engineering and the hydrologist to become familiar with benefit-cost analysis. Cross-training and developmental assignments can be used to promote this mutual knowledge.

There are some major concerns in analyzing the economic aspects of structural flood control measures. The most important is obtaining accurate, timely and compatible H&H studies. In many cases, the frequency with which flooding can be expected is much more critical to average annual damages and benefits than the dollar damage estimate for a particular flood stage. With large basin and urban studies being

performed almost totally with computer assistance, data which is compatible, both geographically and operationally, between economics and H&H is a tremendous help. Having H&H data that have been reviewed and approved before completing the economic analysis can save many weeks of revision and duplication. A good understanding of the effects of with- and without-project H&H can allow a much better feel for total costs and benefits of a structural measure.

CHAPTER IX

CALCULATION OF INUNDATION REDUCTION BENEFITS FOR NONSTRUCTURAL MEASURES

Nonstructural measures generally have negligible effect on any hydrologic or hydraulic relationships. Nonstructural measures primarily modify the stage or elevation-damage relationship. The exceptions to this rule are the usually minor and localized effects of floodproofing by use of landfill and relocation of structures from the floodway. The consequences of each type of nonstructural measure on the elevation-damage relationship and the procedure for measuring the subsequent benefits are described below.

FLOOD WARNING AND RESPONSE

Flood warning and preparedness systems improve a community's capability for accurate and timely forecasts of damaging floods. They provide for the communications channels, information, and resources necessary for individuals to safely evacuate, and for floodplain occupants to take effective damage reduction actions. Warning and preparedness systems incorporate six essential elements:

1) Monitoring is done by a radar system for early detection of weather patterns, and rain and stream gauges that monitor the magnitude and effect of storms.

2) Forecasts for the location, magnitude, and time of flood crests are calculated after entering the gage information into flood forecast models.

3) Warnings are given to floodplain occupants and flood fighting teams to take emergency actions.

4) Damage prevention actions include moving building contents and vehicles, shutting off and disconnecting equipment, rescheduling business operations, sealing entrances, and installing temporary barriers.

5) Evacuation is the process of facilitating orderly, safe movement of floodplain occupants from areas where there is the potential risk of physical harm.

6) Finally, there is the continual management of the warning and preparedness system to maintain the physical integrity of the monitoring and warning equipment, to insure the timeliness of the forecasting model, and to maintain the public awareness of the flood threat, warning messages and channels, and what actions to take in the event of an emergency.

The greatest potential lead time is limited, regardless of the forecasting equipment, by the size of basin, topography of the basin, the source of flooding, and the magnitude of flooding. Without the ability to forecast the amount and location of precipitation before it hits the ground, the forecast lead time is limited by the time of concentration, the amount of time in between when precipitation hits the ground and when it reaches the area with the potential flood hazard. Figure IX-1 shows how inundation lead time will vary with the frequency of the flood event.

The benefits of a flood warning and preparedness system depend on the extent and quality of investment made in all of the elements listed above. These benefits are measured by the incremental level of damages and cost prevented by a new system over and above what is already provided by the National Weather Service and community flood warning service programs.

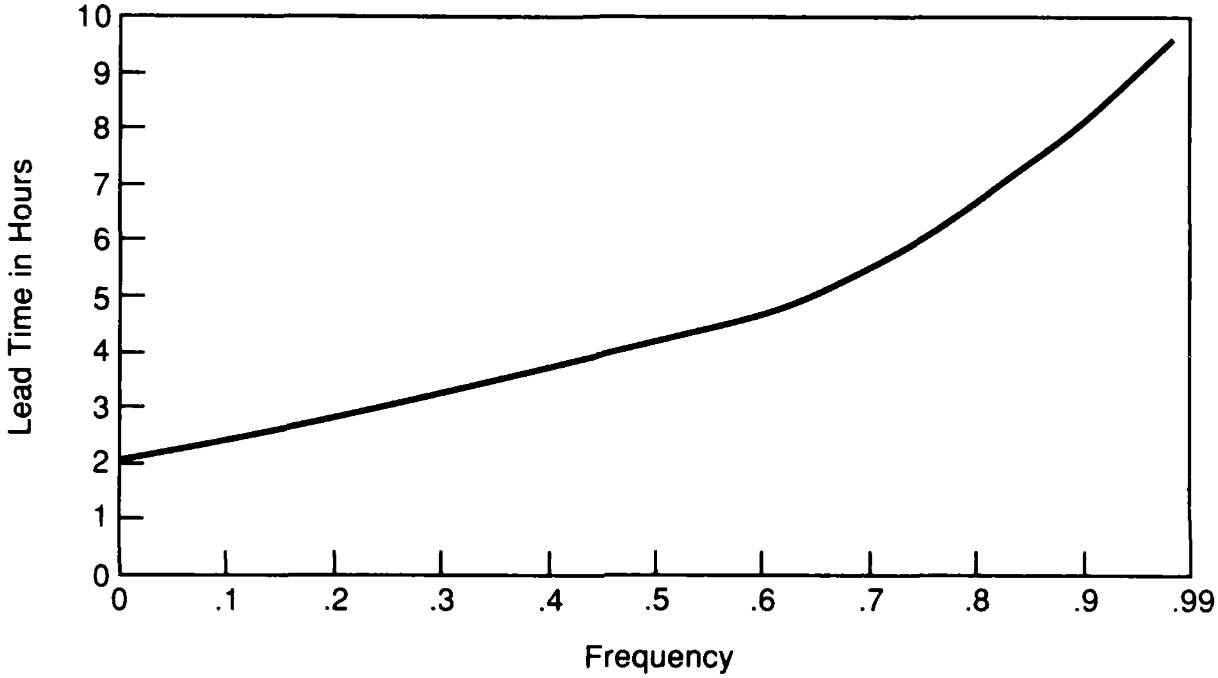
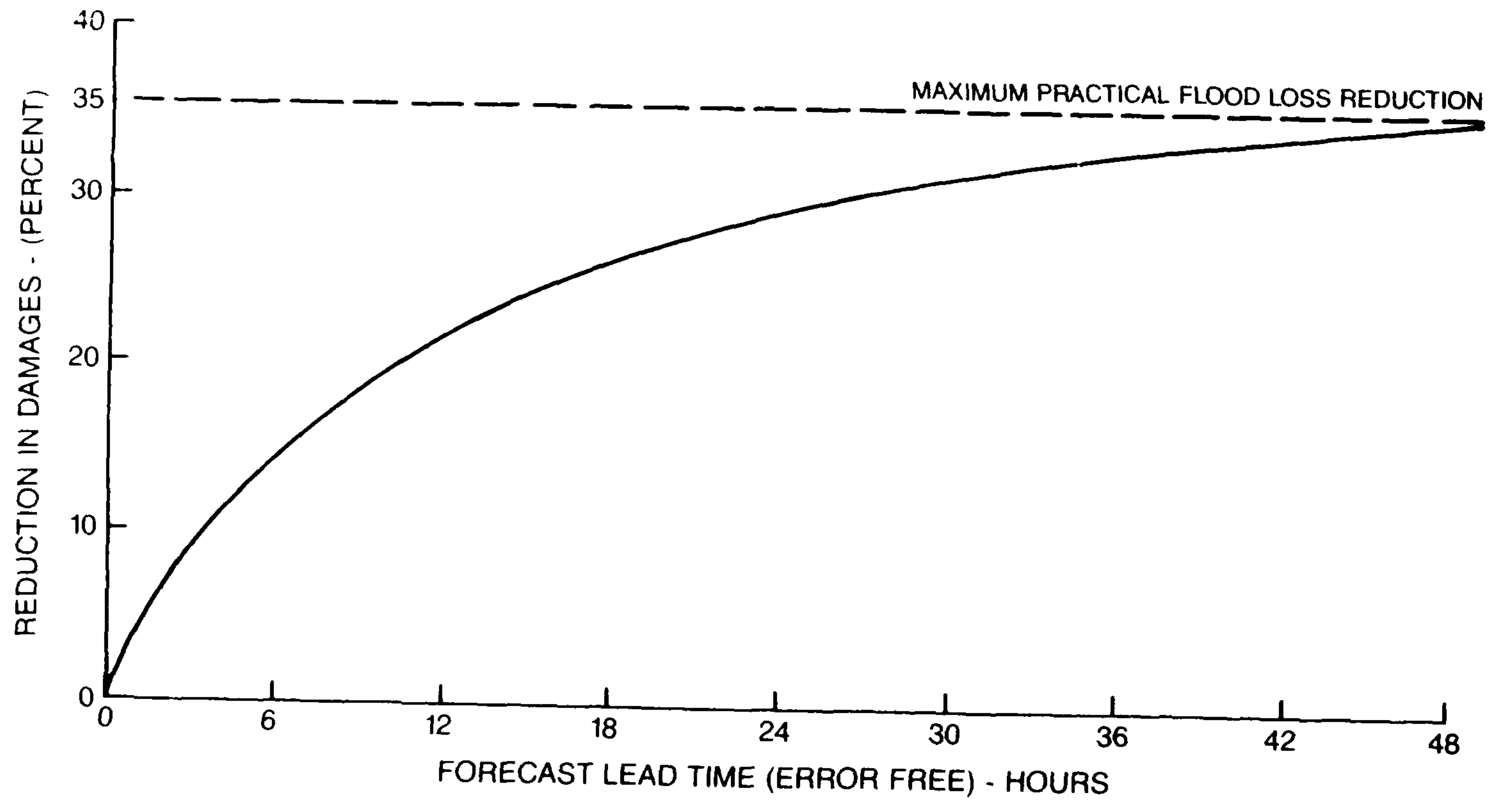


FIGURE IX-1 FREQUENCY - LEAD TIME

The benefits of warning systems depend on the following: 1) the accuracy and timeliness of the forecasts; 2) timeliness, informativeness, coverage, and credibility of the warning message; 3) the reliability of the forecast system to consistently give accurate site-specific, and timely flood predictions; and, 4) the degree and the effectiveness of the response by individuals, businesses, and local governments. Since much of benefits may not be realized without each part of the system operating, and there is a great deal of uncertainty involved in how well each of these components will operate, the benefits of warning are very difficult to evaluate. There is no specific degree of protection below which residual damages are curtailed. Instead, judgments must be made as to how well each of these systems will operate. Other significant problems are the lack of a track record in performing benefit/cost analysis and the even more significant lack of post-flood study to see how well flood warning and preparedness systems have performed.

Benefit calculations for warning and preparedness, when they have been made, generally are limited to physical inundation reduction benefits. This is primarily because of the lack of case studies that would help determine the effect of warning systems on non-physical cost, location, or intensification benefits.

A basic tool for evaluating benefits of warning and preparedness measures is the lead time-damages prevented function. This function was developed by Harold Day, and has been used by researchers ever since to determine the amount of damage that can physically be prevented within a given amount of time. The Day leadtime-damages prevented curve is illustrated in Figure IX-2. Day's curve assumed a 100% response, which



AFTER DAY (1970)

FIGURE IX-2 FLOOD WARNING RESPONSE MAXIMUM PRACTICAL FLOOD LOSS REDUCTION

presumes that all of the affected population will receive the message, know what to do, have the inclination and the capability to respond. (See Day, Harold. "Flood Warning Benefit Evaluation-Susquehanna River Basin" NOAA Tech Memo. WBTM HDRO-10, March, 1970.

The New York District's 1985 feasibility report Flood Emergency Preparedness System: Passaic River, New Jersey and New York, 1984, presented modification of the Day curve with more conservative assumptions on the extent of response. The degree and the effectiveness of the response were believed to depend on the means by which the message is received, with larger responses expected for a direct warning than a warning broadcast over the media.

The prevention of income losses was another benefit illustrated in Robert Kates' 1965 study of flood losses in the Lehigh Valley. Kates presented a business downtime function which showed that flood emergency costs, such as flood fighting, and police and fire custodial safety and traffic direction services, can be expected to increase as part of the costs of warning and preparedness. Efficiencies in delivering emergency service may occur with flood forecasting. The extent of these efficiencies have not been well documented.

Other non-physical costs, such as floodproofing, the administrative costs of flood insurance, temporary relocation, and land market value which cannot be expected to change substantially with warning and preparedness.

In areas subject to high velocity floods with limited lead time, public safety considerations may override the need for NED justification.

PERMANENT (DRY) FLOODPROOFING

Permanent or dry floodproofing includes actions taken in a dry, non-emergency period to reduce potential flood losses. Permanent floodproofing is generally identified with individual properties. Even measures normally thought of as structural, such as levees and floodwalls, are defined as floodproofing.

The measures described above under warning and preparedness are only activated in the case of imminent flooding. The floodproofing measures described here are permanent and usually require no action in the event of an emergency to make them operable. The measures have the obvious advantage of not being subject to a logistical constraint. Because of this advantage, floodplain activities can be assured of a more specific degree of protection and a consistent modification of the stage-damage function than what is found with warning and preparedness measures.

The degree of protection is, however, site specific. Floodproofing also leaves a high level of residual risk to individuals, because access to and from the structure may be blocked by floodwater and this will present a danger to individuals trying to enter or leave. There is also the threat that floodproofing may fail, causing as much or more damage than would have occurred without the floodproofing.

Permanent floodproofing devices can fall into three distinct categories:

1) Raising, which includes landfill, piers, and high foundations; 2) closures, which include non-porous construction material and permanent blockages; and, 3) barriers, which includes floodwalls and

levees. All of these categories include measures that can be applied to retrofitting existing structures or to new construction. Raising merely involves an adjustment in the building elevation in computing residual flood damage. There is the danger of structural failure to buildings elevated by piers during high velocity events. Benefits for closures can only be considered up to a point where hydrostatic pressure might causing problem. A particular building might only benefit from closures when flood levels are three feet or less above the first floor.

PERMANENT RELOCATION

Permanent relocation is the complete evacuation of existing activities to locations not susceptible to flood damage. Relocation may consist of 1) the physical movement of structures to new locations; 2) the demolition of structures at flood-prone locations and construction of new buildings at different locations; or, 3) the demolition of structures and provision of funds for purchase of new buildings. In all of these three cases, the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) requires that the agencies implementing the relocation provide funds for moving and resettlement to displaced residents. It should be noted that any costs of relocation beyond the normal moving expences to satisfy the requirements of the Relocation Act are not normal NED costs.

Relocation has often been combined with other measures, particularly reservoirs and levees. Traditionally, relocation has served to facilitate

other measures by clearing land for construction. Only in recent years has relocation served as a damage reduction feature in its own right.

Permanent relocation consists of: 1) the purchase of all buildings and associated land within designated reaches and flood zones; 2) relocation assistance in the form of direct grants to individuals for their resettlement costs; and, 3) assistance to local government in planning for new uses for flood-prone property.

Relocation projects, like other nonstructural measures, generally have a negligible effect on the stage-discharge relationship. However, there can be a significant drop in stage on small streams for high levels of discharge when structures are removed from the floodway and the flow is unrestricted.

A 1985 review of Corps' experience found permanent relocation has had limited use as the primary project component. It has been most successful when combined with other mitigation measures, and for areas with severe and repeated flood damage, within the 25-year floodplain (Moser, 1985).

Relocation is the only measure where the residual damages for the affected activity can be assumed to be zero for all levels of flooding.

Benefits from permanent relocation can be classified into five categories: 1) the value for the new use of the vacated land; 2) reduction in damage to public property, such as roads and utilities; 3) reduction in emergency costs; 4) reduction in the administrative costs of disaster relief; and, 5) reduction in the flood insurance subsidy. The first category represents the location benefit. The other four categories represent benefits from the reduction in the publicly borne costs of flooding.

There is no benefit taken for reduction in private flood damage because it is assumed that expected flood losses are, for the most part, reflected in lower property values. So, because the reduced property values lower the costs of relocation, it would be double-counting to also consider the costs of the physical damages.

The location benefit is critical to the economic justification of a relocation project. It is unlikely that a relocation project can be justified if the evacuated property does not have considerable value in its new use. The location benefit is measured by the value of the floodplain in its new use. Unlike location benefits for structural projects, the value of the property in its old use is not subtracted because that value has already been considered in the purchase price of the relocated property.

The location benefits for agricultural or other income-producing activities can be determined by estimating the net income of the projected activity. An example of the net income approach to location benefits is given in the section on location benefit in Chapter X. Location benefits can also be determined by the hedonic price and contingent value approaches illustrated below.

The hedonic price procedure measures the internalized value of nonmarketable attributes. An example of this approach would be determining the value of open space land by comparing the market value of adjacent property to comparable property without the open space land nearby. The difficulty with this approach is finding "comparable" property with buildings and lots of similar size, condition, accessibility, character, and availability of community services.

The public damage reduction considered in the calculation of permanent relocation benefits includes reduction in damages to streets, sewers, water supply lines, lighting, electrical transmission lines, gas lines, and public vehicles. Details of estimating the damage to these facilities are found in Appendix A. Care should be taken to consider any residual costs to transportation facilities and utilities that would remain to service areas outside the floodplain or any new activity that moves in as a result of the relocation.

Emergency flood costs, including the administrative costs of disaster relief, can be measured by the procedures described in Chapter VII. Permanent relocation would have the following implications to the emergency costs listed in Chapter VII: it can be assumed that flood forecasting costs could not be substantially reduced, because they are generally applied to a much larger area than would be affected by a relocation. Warning, temporary evacuation, flood fighting, reoccupation costs, and administrative costs of disaster relief could be virtually eliminated, depending on the new use of the evacuated floodplain. The magnitude of emergency costs should be estimated for various land uses and frequencies of flooding. The benefit will be the difference in expected costs with and without the relocation project.

Unlike structural projects, permanent relocation is concerned with the reduction in the flood insurance subsidy, rather than just the elimination of the administrative costs of flood insurance. This subsidy, like the emergency costs mentioned above, will cause distortions in the market value of land. The market value is distorted upward because the subsidies reduce the out-of-pocket costs to the landowners and renters.

The flood insurance subsidy is determined by deducting the average annual insurance premium from the average annual expected insured loss and the administrative costs of flood insurance. The insured loss assumes coverage of all physical costs including damage to the building structure, damage to contents, and cleanup of the structure and contents. It excludes damages to certain contents, such as paintings or antiques, damage to outside property, and requires a $500 deductible per loss for structure and contents. An example of the flood insurance subsidy benefit for a single residence is given below:

Table IX-1

Flood Insurance Subsidy Calculation

Item	Amount
House Value	$15,000
Contents Value	8,000
Agency Cost	
Average Annual Damages	1,450
Agent Fee (15% of the premium)	15
Other Administrative Costs	20
Total	$1,485
Policy-Holder's Cost	
Annual Insurance Premium ($.40/$100 of structure value and $.50/$100 of contents)	100
Annual Uninsured Damage	150
Annual Expected Deductible	300
Total	$550
Average Annual Flood Insurance Subsidy	$ 935

An additional subsidy which can distort the value of floodplain property is the tax savings from casualty claims on Federal and state income tax forms for individual taxpayers. The magnitude of the casualty deduction is limited to uninsured and otherwise uncompensated losses. Only the portion of uncompensated loss that exceeds 10 percent of the taxpayer's adjusted gross income is deductible. Even insured properties will still have uninsured losses on deductibles and types of losses excluded from coverage.

CHAPTER X

OTHER BENEFITS

While inundation reduction benefits have constituted the great majority of economic justification for flood projects, they do not measure the total economic gain for flood loss reduction. Location and intensification benefits represent increases in economic welfare because reduction in flood risk allows for higher economic use of the property. These benefit categories are described below. Also described are benefits for advanced bridge replacements that represent betterments by way of extending the life and improving conditions of stream and river crossings. Finally, this chapter describes negatives benefits, which results from damages induced by flood control structures to neighboring properties.

LOCATION BENEFITS

Location benefits occur when a reduction in the level of flood risk makes it profitable for new activities to locate in the floodplain. Location benefits are determined by the increase in net income or property values brought on by the new use.

Criteria for Location Benefits: There are three criteria that must be met before location benefits can occur. These include:

1) The land must become relatively flood-free. At a minimum, there must be less than a one percent chance of a flood occurring in any year.

2) The land must go to higher economic use than it would without the project.

3) The land must have a location advantage over alternative sites. Physical, aesthetic, infrastructure attributes of the floodplain sight must be significant enough to allow considerable location advantages over alternative flood-free locations. This location advantage must be significant enough to allow an increase in net profit over and above alternative sites over and above any expected residual flood damage. This criteria can be put to a test, which is illustrated by the example given in Table X-1:

TABLE X-1

TEST FOR APPLICABILITY OF LOCATION BENEFITS

Present Value at Year 0	Floodplain Site	Non-Floodplain Site
Economic rent	$10,000	$6,000
Expected loss, without flood protection	$ 5,000	0
Expected loss, with protection	$ 1,000	0

Location decision without flood protection

($10,000 - $5,000) < $6,000 The activity will select the flood-free site.

Location decision with flood protection

($10,000 - $1,000) > $6,000 The activity will select the floodplain location.

Economic rent is defined here as the net income of the activity occupying the land.

Since economic rent minus expected flood loss is less than the economic rent for the non-floodplain site without project, but greater with protection than the economic rent of the non-floodplain

site than a the project can be assumed to meet the location advantage criteria for location benefits.

4) Finally, there must be a sufficient demand within the affected area to support the development of the new activity. This can be determined by the economic base study and land use allocation process described in Chapter VI.

Location benefits build on the procedures described in Chapter VI, for the calculation of future conditions without-project. Before location benefits can be calculated, it is necessary to determine the spatial requirements for various land uses, based on demographic and economic projections. For many Corps studies, it is assumed that land use requirements will be the same with and without the project. However, the distribution of activities may change, depending on the extent and location of flood protection. For example, portions of projected requirements for 1,000 additional acres of industrial land use can be allocated to newly protected floodplains, if that area has a location advantage over alternative flood-free sites.

There are three primary measures for location benefits: net income differences, threshold levels and changes in market values. These three methods do not necessarily lead to the same results. At least two of the procedures can be applied and to help determine which procedure is the most appropriate. Justification should be made in each case as to why a particular method was selected.

NET INCOME DIFFERENCE

The net income difference approach is the most direct procedure for measuring the location advantage of any site. It is the approach that

most explicitly follows the prescribed definition of location benefits. It is crucial that advantages of the floodplain versus alternative sites be quantifiable. It is also necessary to be able to identify the change in net income for the displaced activity. Net income differences consists of the following six steps:

1) Calculate the net income of the new activity for the floodplain site and subtract the net income at the alternative location. The costs of land and residual flood damage are excluded in calculation of net income for the floodplain site at this point.

2) Calculate the net income for the displaced activity (where costs exclude economic rent and residual flood damage) and subtract the net income at the alternative site.

3) Subtract the loss in net income of the displaced activity (Step 2) from the net income of the new activity (Step 1).

4) Subtract the average annual residual damages to the new activity from the increase in net income determined in Step 3.

5) The without-project damages to the displace activity should be added to the total benefit.

6) Any external flood damage caused by the new activity should be deducted from any increase in net income (See induced flood damages, later in this chapter).

An example of the net income method is given below:

Pres. Value of Avg. Ann. Income	New Activity	Displaced Activity
Net Income Floodplain Site	$550,000	$400,000
Net Income at the Alternative Site	$390,000	$370,000
Expected damages without project	$150,000	$ 40,000
Expected damages with project	$ 10,000	$ 7,000

Step One: $550,000 - $390,000 = $160,000

Step Two: $400,000 - $370,000 = $ 30,000

Step Three: $160,000 - $30,000 = $130,000

Step Four: $130,000 - $10,000 = $120,000

Step Five: $120,000 + $40,000 = $160,000

Step Six: No significant induced damages.

Total Location benefits = $160,000.

Threshold Method. The threshold level is defined by the amount of flood protection that would be required for an activity to be indifferent between the floodplain location and the alternative flood-free location. When the threshold level has been identified, the benefit can be determined by estimating what damage reduction there would be for the new activity over and above the threshold level. Any benefits from reduction in damages to the displaced activity must be subtracted if it has already been considered under inundation reduction benefits.

Assume that there are two industries that would find a location advantage to a floodplain site if expected flood damages were reduced

below a threshold. Table X-2 shows the firm's net income at the floodplain and alternative site, the expected flood damage without flood protection, and threshold level of protection necessary to induce a floodplain location. Figure X-1 shows that firm I_1 is indifferent to the floodplain location at T_1 at the 2% or 50-year flood level, and likely to choose the floodplain location for anything above that level of protection. Firm I_2 is indifferent at point T_2, the .05% or 20-year flood level.

TABLE X-2
THRESHOLD FOR LOCATION DECISIONS

	Industry 1		Industry 2	
	Floodplain Site	Flood free Site	Floodplain Site	Flood free Site
Net Income Minus Expected Flood Loss	\$47,500	\$50,000	\$49,200	\$50,000
Thres. Level for Residual Flood Loss	\$2,500		\$800	
Exp. Ann. Flood Loss Reduction	\$6,000	0	\$5,000	0
Threshold Level of Protection	.02 or 50-year flood		.002 or 500-year flood	
Expected Annual Location Benefits	\$3,500		\$4,200	

The benefit under threshold level is equal to the expected damage for the new activity would be if located in the floodplain without the project, minus the expected residual damages with the project. To avoid

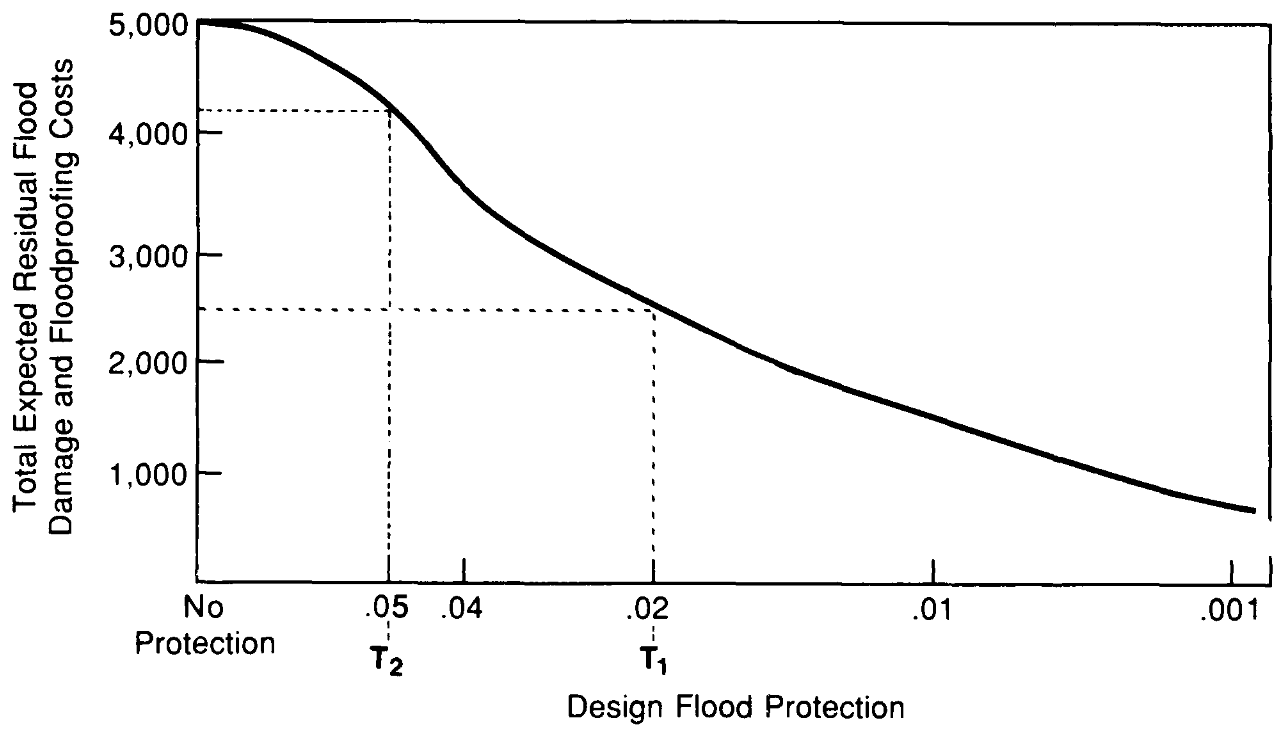


FIGURE X-1 THRESHOLD METHOD FOR COMPUTING LOCATION BENEFITS

double counting, the expected annual damage for the displaced activity should not be counted as a benefit.

Market Value of Land. The market value of land is the simplest of the three methods in theory and the most difficult in practice. The market value method assumes that the value of the property will increase by an amount equivalent to the increased net income. There are many factors that can influence changes in property value, including perceptions of the level of residual flood risk. The change in market value is difficult, at best, to project, but it is also necessary to segregate the individual factors that contribute to changes in property values. It is therefore recommended that the market value approach be limited to a verification of the other techniques.

Limitation on Location Benefits. The limit on the amount of location benefits is the expected damages that the new activity would have for without-project conditions. This limitation is a corollary to criteria number two, listed above. The rationale is that the flood protection will not account for a change in land use productivity beyond the reduction in expected flood losses.

INTENSIFICATION BENEFITS

Intensification benefits are increases in net income where land use or type of economic activity does not change under with-project conditions.

Intensification benefits have most often been applied to agricultural areas, realized through increased net income from crop production. This benefit category has had limited application to urban land uses.

Intensification benefits can be substantiated when there is evidence that business operations have been considerably scaled back from what they would be with flood protection.

Intensification benefits apply to business activities where there is an increase in net income due to a change in the method of operation. Intensification benefits will occur when a reduction in flood threat is significant enough to allow additional investment in labor or capital.

Intensification benefits can theoretically apply to residential property. However, increases in net income or market value over the cost of intensification would generally be small and difficult to verify. The benefit is equal to the increased net income from the intensification of the operation at the floodplain site, minus any increases in residual flood damages over what there would be if the intensification did not occur.

The same three methodologies used in evaluating location benefits--the net income, threshold, and market value approaches--are applicable to calculating intensification benefits. The specific procedures are somewhat simplified because there is no need to consider displaced activities.

The intensification benefit for each enterprise under the net income approach is given by the following formula:

$$B = (I - C_i) - (F_i - F_p)$$

where B is the intensification benefit
- I is the gross income of the intensified operation
- C_i is the annualized cost of the intensification
- F_i is the annual expected costs of flooding to the intensified operation, and
- F_p is the annual expected costs of flooding under pre-intensification conditions

Under the threshold method, it is necessary to know the extent of flood protection needed to induce the intensification. As with location benefits, the benefit is simply the average annual expected flood damage avoided to the intensified activity over and above the threshold level of damage reduction necessary to induce intensification

Intensification benefits under the market value method would be the increase in market value for the intensified operation, minus the annualized cost of the intensification.

ADVANCED BRIDGE REPLACEMENT BENEFITS

If a railroad, highway, street, or pedestrian bridge is replaced as the result of a flood control project, a benefit can be claimed to at least partially offset the cost of the bridge replacement. Advanced bridge replacement benefits are taken for the period that the useful life of the bridge is extended by the project.

AFFLUENCE BENEFITS

Affluence benefits are an inundation reduction benefit that based on an increase in residential content value that coincides with an increase in residential income. The basis for the affluence factor was described in Chapter VI. An example calculation of affluence benefits is given below:

Average Home in Floodplain

Structure Value	$40,000
Contents Value	$20,000

Average Annual Benefits, Existing Conditions

Structure -	$500 per house
Contents -	$200 per house

Number of homes protected by project - 1,000
OBERS per capita income growth rate - 2%
Current year (existing conditions) - 1980
Base year - 1990
Interest - 8 1/8%
Project Life - 100 years

Calculate benefits for protecting projected increase in content value:

Contents now are valued at 50% of structural value. They can increase to 75%.. a 50% increase. Benefits can increase at the same rate ... $200 to $300. The annual increase in benefits/house = 2% x $200 to $300. There is $100 increase @ $4 per year = 25 years to reach the 75% limit. There is no discounting to the base year, which is 10 years off. Until then, there is a $4 per year increase, for a total of $40. The total benefit will be the $40 + the present value of the benefits realized after the base year. This is computed by multiplying the remaining $60 by a present worth factor of (.61215), which = $37. The average benefit per house is $40 + $37 = $77, multiplied by 1,000 houses = $77,000.

NEGATIVE BENEFITS: INDUCED FLOOD DAMAGES

Induced flood damages can occur as the result of a levee or floodwall constricting a river channel and causing an increase in river or stream stages for various frequencies of flooding. Channel enlargement projects can also induce flood damages to downstream locales by raising flood

levels and increasing flood velocity. It should be noted that only large levee, floodwall, and channel projects have any appreciable influence on surrounding locations. However, when hydraulic engineers are able to determine a significant increase in flood stage, induced damages should be calculated and treated as negative benefits.

CHAPTER XI

DISCOUNTING PROCEDURES

INTRODUCTION

Corps of Engineer water resource development projects typically involve many alternatives, require several years to plan and install, and provide benefits and incur operation, maintenance and replacement (OM&R), and sometimes deferred installation costs for many years after implementation. They typically incur the greater proportion of their costs early, during the construction (or installation) phase. Benefits then accrue over an extended project life, often increasing over time.

Recognizing that a dollar in hand is not worth the same as a dollar 1, 10, or 25 years hence, the problem confronting the water resource development analyst is to convert unevenly distributed cost and benefit streams to comparable measures. The concept of "equivalence", that is that payments that differ in total magnitude but that are made at different dates may be equivalent to one another, enables such comparisons to be made. (Throughout the following discussion, the word payment is used in a generic sense and could be replaced by either the word benefit or cost.) Discounting and compound interest procedures provide the analyst with the tools needed to make these comparisons. The purpose of this chapter is to describe and illustrate, with examples, some of the important concepts and procedures needed to compare costs and benefits over time.

A typical "evaluation setting" for a Corps water resources development project is depicted in Figure XI-1. Some of the important principles and terms associated with this setting are described below.

The <u>study year</u> is the year the current study (evaluation) will be completed. As a study proceeds through the planning process, the study year will move to the right on the time line depicted in Figure XI-1. <u>Existing conditions</u> are the measures of economic factors, and water and related land resources, existing at the time of the study (normally referenced to the end of the study year). These conditions serve as the bases for <u>future projections</u> under both with- and without-project conditions. Since benefits and costs must be expressed in constant dollars, the conditions at the time of the study also determine the <u>price level</u> to be used in the analysis.

The <u>beginning of construction</u> is the year in which construction begins, while the <u>base year</u> is the first year in which the project is expected to become operational. For the purposes of this discussion, the <u>period of analysis</u> is defined as the time horizon, beginning with the base year, for which project benefits and deferred installation and OM&R costs are considered. For most Corps' studies, the period of analysis is either 50 or 100 years. When comparing alternatives, the same base year and period of analysis should be used for all plans being evaluated.

The <u>expected annual benefits and costs</u>, (often referred to as <u>benefit and cost streams</u> in benefit-cost analysis), are the estimates of the annual benefits and costs that are expected to occur during

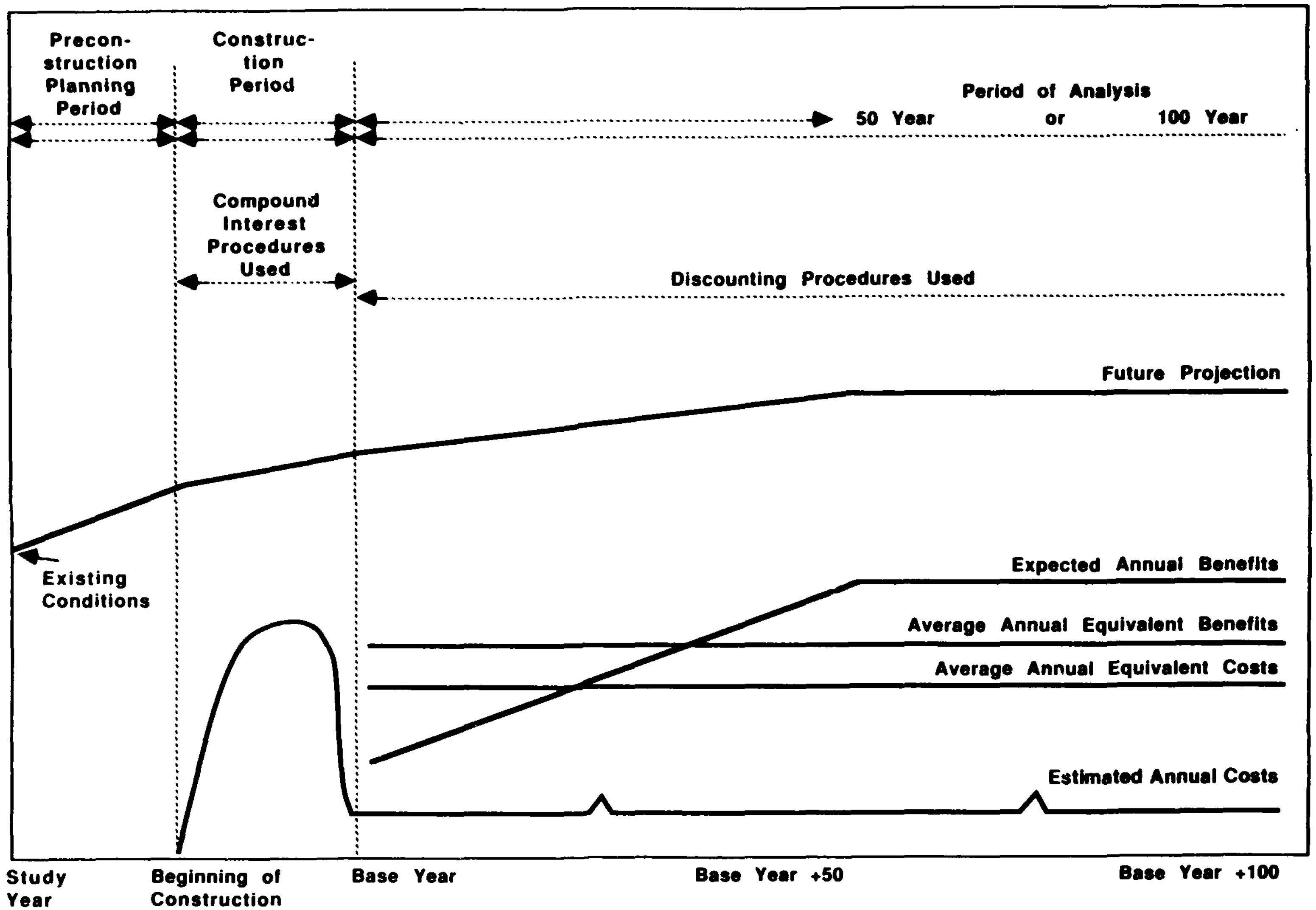


Figure XI-1. Evaluation Setting

the construction period and project life. Generally, benefits are only anticipated after plan implementation, but for some projects benefits can also occur during the construction period. The analytical problem is to convert the varying benefit and cost streams to their equivalent and comparable average annual measures over a common time period, that is the period of analysis.

An intermediate step is required to convert the benefit and cost streams to equivalent average annual measures; the present worth of the streams must first be determined. The **present worth** for each stream is the single value, in the base year, that is equivalent to the many payments that would accrue from that stream. **Discounting** is the procedure used to reduce future values, those occurring during the project life, to their present worth in the base year. **Compound interest procedures** are used to determine the present worth of benefits accrued and interest on construction incurred during the construction period, prior to the base year.[1] As will be illustrated in the examples that follow, the present worth value for the entire benefit or cost stream is dependent on the magnitude, number, and timing of individual payments as well as the appropriate discount and interest rate used in the analysis.

The **average annual equivalent benefit**, generally termed the average annual benefit, is then defined as the amortized value over the period of analysis of the present worth (in the base year) of the

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[1] In some texts, present worth refers only to discounted future payments, while present value refers to the equivalent value (in the base year) of payments received prior to the base year. For the purposes of this manual, present worth and present value will be used interchangeably.

benefit stream. The average annual or amortized value, therefore, is a constant amount of benefit, occurring each year during the period of analysis. This constant stream of benefits is equivalent to the present worth, in the base year, of the entire benefit stream. Obviously, the constant stream of average annual values is also equivalent to the benefit stream itself. **Average annual equivalent costs** are similarly defined.

INTEREST AND DISCOUNT RATES

As noted above, the interest and discount rate used is important for determining the magnitude of the present worth and average annual value of a particular benefit or cost stream. In business, **interest** is usually defined as the charge for the use of money. In more general terms, interest is considered the return obtainable from the investment of capital. The **interest rate** is the ratio of gain received to amount invested, or the amount paid to amount borrowed. Somewhat similarly, the **discount rate** is the ratio between the value of a future payment and its present worth at some specified time, (the base year in water resource development studies). Since interest and discount rates are critical to the analysis, decision as to the appropriate rates to use must be made.

Starting in 1969, the discount rate for water resource development studies is based on the average yield, during the preceding fiscal year, of marketable United States securities, which, at the time of computation, have 15 years or more to maturity.

A policy decision was made by the Water Resources Council (WRC) that the discount rate for FY 1969 would be 4-5/8 percent, and that the rate should neither be raised nor lowered more than 1/4 of 1 percent in any year. This WRC rule was enacted into law in 1974. The Federal discount rate to be used in Corps' studies is distributed annually by the Office, Chief of Engineers in the Fiscal Year Reference Handbook. In FY 1987, the discount rate was 8 7/8 percent. The Federal discount rate is also to be used for calculating interest during the construction period.

INTEREST RATE FORMULAS

Some examples will be presented later to illustrate the discounting concepts described above. The basic interest rate formulas most frequently used in benefit-cost analysis are first presented. The derivation of these formulas is described in most engineering economy and business finance textbooks, such as Principles of Engineering Economy, 1982, by Grant, Ireson, and Leavenworth.

Symbols:

The symbols used in these formulas are:

i = interest or discount rate for a given interest period, usually a year.

n = number of interest periods.

P = present worth of a sum of money.

F = a sum of money at the end of n periods from the present worth date

that is equivalent to P with interest i.

A = the end-of-period payment or receipt in a uniform series continuing

for the coming n periods, the entire series equivalent to P at interest

rate i.

<u>Formulas:</u>

The compound interest formulas most commonly used in benefit-cost analysis are:

Given P, to find F. $F = P(1+i)^n$ (1)

Given F, to find P. $P = F \frac{1}{(1 + i)^n}$ (2)

Given P, to find A. $A = P \frac{i(1 + i)^n}{(1 + i)^n - 1}$ (3)

Given A, to find P. $P = A \frac{(1 + i)^n - 1}{i(1 + i)n}$ (4)

The interest portions of the above formulas, e.g., $(1 + i)^n$ in Equation 1, are often called interest factors. Values for these factors for various interest rates and time periods are provided in Interest Factor Tables in most engineering economy and business finance textbooks. In addition, the Corps annually computes and publishes the values for these factors, based on the current Federal discount rate, in its <u>Fiscal Year Reference Handbook</u>. With the advent of micro-computers, and especially the accompanying spreadsheet software, these formulas can also be readily incorporated into analytical packages, minimizing the re-

analysis effort required when interest rates change. In fact, most of the larger, computerized flood damage programs used on main frame-computers have had these formulas incorporated into their analytical package for some time. Following is a brief description of the formulas and associated factors. Subsequent examples will illustrate their application in benefit-cost analysis.

Single payment, compound amount factor (Equation 1). This is the amount that will accumulate when $1.00 is invested at compound interest for a given period of time and the interest is not withdrawn. The single payment, compound amount, interest factor at 8 percent is $(1 + .08)^1$, or 1.08, for one year, $(1 + .08)^2$, or 1.17, for two years, and so forth. Similarly, the compound amount of $1 in one year at 8 percent interest is $1.08, in two years $1.17, and so forth.

Single payment, present worth factor (Equation 2). This is the amount that must be invested at the beginning of the period of analysis to have a value of 1 in a given length of time and at a given interest rate. For example, the interest on $92,593 at 8 percent for one year is $7,407, and the interest and principal one year hence is $100,000. The present value of $100,000 received 1 year hence at 8 percent is, therefore, $92,593 and the single payment present worth factor is 0.92593.

Capital recovery factor (Equation 3). The pay back of a financial obligation (both principal and interest) in equal installments is called amortization. The amortization factor is also referred to as the partial payment, the annualizing, and, most frequently, the capital recovery factor. It is the amount of the installment required to retire a debt of $1 in a given length of time. The product of the capital recovery factor

and the present worth of a benefit (or cost) stream is the average annual (equivalent) value of that stream.

Present worth of annuity (Equation 4). The present value of an annuity factor is the reciprocal of the capital recovery factor. It is a measure of the present worth of annual payments of $1 over a specified period of time. Since the present worth of an annuity is the reciprocal of the capital recovery factor, their product must always equal one.

END-OF-ACCOUNTING INTERVAL CONVENTION

Before presenting specific examples, one additional concept needs to be discussed. The end-of-accounting interval convention is typically used in discounting studies. That is, all payments that occur throughout an accounting interval (most typically a year, but other intervals such as months or quarters can also be used) are treated as if they occur at the end of that accounting interval. This convention greatly simplifies the application of discounting conversions and, usually, does not introduce significant error.

EXAMPLES

SINGLE VALUES

The simplest of cases is where there is a single payment for which the average annual value is to be determined. Remember, for Corps' benefit-cost studies, the objective is to compute the average annual value, over the period of analysis, for all payments. To do this it is necessary to first convert all prior (during the construction period) and

future (during the project life) payments to their present worth values at the beginning of the base year, and then convert the sum of present worth values to average annual values.

If, in the single value example, the payment occurred at the end of the year immediately preceding the base year, the value of the payment would be the same as its present worth.[2] It would then only be necessary to convert the present worth, P, to an average annual, A, value for a specified interest rate, i, and number of years (period of analysis), n. Equation 3, above, is used for this conversion. The compound interest factor that results from solving the interest portion of this equation for a particular interest rate and time period is commonly referred to as the capital recovery factor. It indicates the amount of annual return required (for the particular interest rate and time period) to "recover" the value of the investment made. As an example:

EXAMPLE 1:

Amount of payment at base year (present worth)	= $1,000
Interest rate	= 8%
Number of years in period of analysis	= 50
Compound interest formula used (equation #)	= 3
Average annual value = 1,000 x .08174[3]	= $82

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[2]The base year, the first year following implementation of a plan, is year one in the period of analysis. With the end-of-year convention, payments occurring during the base year would have to be discounted one year to determine their present worth value. Payments at the end of the year immediately preceding the base year are present worth values.

[3]The value .08174 is derived either by solving the appropriate portion of Equation 3 with the applicable interest rate and time period (8 percent and 50 years in this example) or by referring to Compound Interest Factor Tables as noted above.

Next, consider the situation where the single payment occurs prior to the base year, (i.e., during the construction period). The present worth of this payment first needs to be computed, before the capital recovery factor can be used to determine the average annual value. Equation 1 can be used for this conversion, although a slight change in the terminology is required. In this situation, the future value (F) being solved for is actually the present worth value, since the timing of the payment occurs before the base year. Likewise, the value of the payment is used as the value of P when solving the equation. This situation is illustrated in the following example.

EXAMPLE 2:

Amount of payment		= $1,000
Interest rate		= 8%
Number of years between prior payment and base year		= 3
Compound interest formula		= 1
Present worth	= 1000 x 1.2597	= $1,260
Number of years in period of analysis		= 50
Compound interest formula		= 3
Average annual value	= 1,260 x .08174	= $103

In the final single value case, consider the situation where the single payment occurs after the base year, during the period of analysis. The first step is to discount the future value (F), to its present worth (P), in the base year. Equation 2 is used for this first step, and then, once again, Equation 3 is used to derive the average annual value from the present worth.

EXAMPLE 3:

Amount of payment		= $1,000
Interest rate		= 8%
Number of years between base year and payment		= 25
Compound interest formula		= 2
Present worth value	= 1000 x 0.1460	= $146
Number of years in period of analysis		= 50
Compound interest formula		= 3
Average annual value	= 146 x .08174	= $12

EFFECT OF TIMING OF PAYMENT AND INTEREST RATE USED

The above three examples not only illustrate the basic discounting principles under the simplest of scenarios, but also the effect of one of the important variables, that is the timing of the payment. In all three examples the number (1) and amount ($1000) of the payment are the same, as well as the interest rate (8%) and length of the period of analysis (50 years). The only variable changed is the timing of the payment relative to the base year, yet the result is three substantially different average annual values. Thus, in the scenario presented above, the average annual equivalent value of a $1,000 payment three years prior to, at the beginning of, and 25 years after the base year is $103, $82, and $12, respectively.

Similarly, the effect of the discount rate used can also significantly affect the results. For example, the following tabulation shows the results of the first three examples when using discount rates of 4, 8 and 12 percent, and a 50 year period of analysis. That is, the present worth and average annual values for a single $1,000 payment

received 3 years prior to, at the beginning, and 25 years after the base year are shown for each of the three discount rates. As can be seen from this tabulation, the higher the discount rate, the lower the discounted value (present worth) of <u>future</u> payments.

	Present Worth Value at			Average Annual Value at		
Timing of Payment	4%	8%	12%	4%	8%	12%
3 yrs before base	$1,125	$1,260	$1,405	$52	$103	$169
Base year	1,000	1,000	1,000	47	82	120
25 yrs after base	375	146	59	17	12	7

STRAIGHT LINE GROWTH

Before addressing straight line growth, it is important to first discuss constant, annual, future values. (It is also important to remember that, in Corps' economic analysis, benefit-cost ratios are determined from average annual, rather than present worth, values.) It is widely understood that if there is a constant stream of annual value of, say, $20,000 for 50 years, the average annual value is $20,000. There is nothing magical about this, since this result is consistent with discounting and analyzing procedures, as demonstrated below:

EXAMPLE 4:

Uniform annual value		= $20,000
Interest rate		= 8%
Period of analysis		= 50 years
Compound interest formula		= 4
Present worth	= 20,000 x 12.233	= $244,700
Compound interest formula		= 3
Average annual value	= 244,700 x .08174	= $20,000

Thus, the average annual value of a uniform stream of values of $20,000, is $20,000. Although somewhat obvious, the above finding also illustrates an important consideration in discounting. That is, when the discount rate is the same as the interest rate, (as for Federal water project analysis), the present worth (or discount) factor for a series of uniform payments is the reciprocal of the capital recovery (or analyzing or *amortization) factor. Regardless of the interest rate,* the product of these factors is, therefore, one, and the uniform and average annual values are the same. With this in mind, discounting of a future stream, including a straight line growth segment, will now be examined.

EXAMPLE 5:

Period of analysis	= 50 years
Growth period	= 25 years
Discount rate	= 8%
Base year payment	= $20,000
Incremental increase in payments per year	= $2,000

The above payment stream is depicted in Figure XI-2. A payment of \$20,000 occurs in the base year (year 1). Payments increase by \$2,000 per year through the 25th year, when the annual payment equals \$68,000. Payments then remain constant at \$68,000 per year for the remaining 25 years of the period of analysis. This linear growth period conforms to a gradient series, typically used in engineering economy studies (Grant, 1982). That is, the series changes at the end of each accounting interval by successively increasing multiples of a fixed sum. The gradient series does not begin until the end of the second accounting interval. If the gradient is g, the amount of yearly increase is then: zero for the first year, g for the second, 2g for the third, and (n-1)g for the nth.

One way to estimate the average annual value of this stream is to repeat the process described for a single payment in Example 3 for all 50 payments. That is, the present worth of each payment would first be determined by multiplying the payment by the appropriate single payment present worth factor derived from Equation 2. The sum of the present worth values for all 50 payments, multiplied by the capital recovery factor derived from Equation 3, would then yield the average annual value. This procedure can be readily accommodated by most micro-computer spreadsheet programs and is incorporated into most computerized flood damage programs with a discounting capability. It is, however, quite tedious and time consuming when automated programs are not available. Several short-cut methods are available, one of which relies on the gradient series present worth factor, (Equation 5), that is, given g to find P.

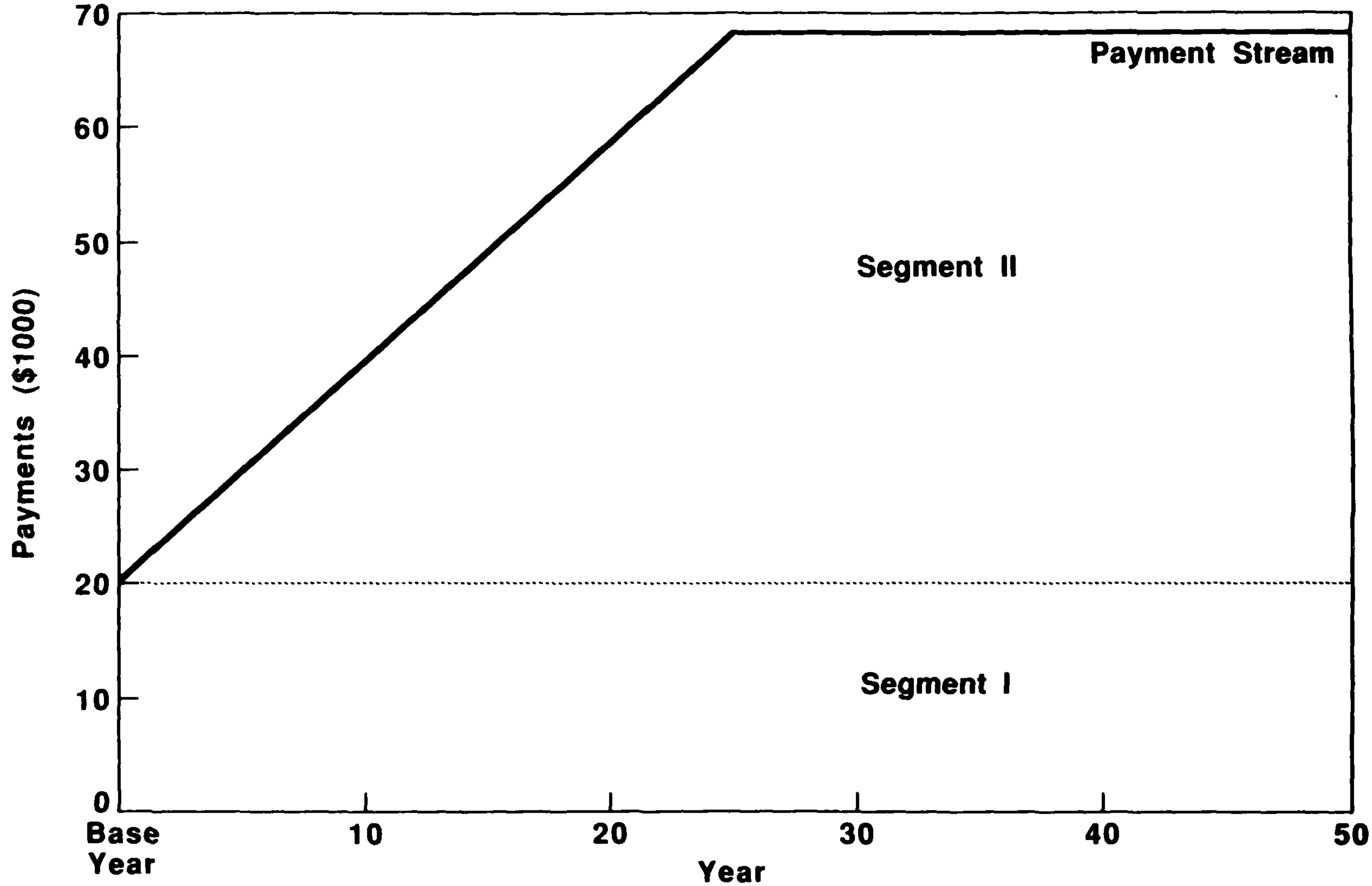

Figure XI-2. Example Straight Line Payment Stream

$$P = g\left[\frac{1}{i} - \frac{n}{i}\left(\frac{i}{(1 + i)^n - 1}\right)\right]\left[\frac{(1 + i)^n - 1}{i(1 + i)^n}\right] \qquad (5)$$

When using the gradient series factor, the payment stream depicted in Figure XI-2 is analyzed in two segments. Segment I represents the constant portion of the payment stream. As illustrated in Example 4 above, the average annual value of a constant payment stream is the annual amount of that stream, or \$20,000 in this example.

The second segment contains two parts: a gradient series increase (Segment IIA), and a constant payment stream (Segment IIB). To find the present worth (in the base year) of Segment IIA, the gradient amount, (\$2,000), is multiplied by the present worth of a gradient series factor for 25 years at 8 percent, (87.80 derived from Equation 5), or \$2,000 x 87.80 = \$175,600. It requires two steps to determine the present worth (in the base year) of Segment IIB. The amount of the payment stream, (\$68,000 - \$20,000, or \$48,000) is first multiplied by the present worth factor of an annuity for 25 years at 8 percent, (10.675 from Equation 4). This yields the present worth of the payment stream (\$512,400 in this example),

at the beginning of year 26 (or end of year 25). This value is then multiplied by the single payment present worth factor for 25 years, (.1460 from Equation 2), to determine the present worth value in the base year, ($74,810). The sum of the present worth values of Segment IIA and Segment IIB, or $250,410 ($175,600 + $74,810), is then multiplied by the capital recovery factor, (.08174 from Equation 3), to determine the average annual value, or $20,470 (rounded) for the 50 year period of analysis.

The sum of the average annual values from Segments I ($20,000) and IIA&B ($20,470) is the average annual value for the entire payment stream, or $40,470.

STRAIGHT LINE GROWTH WITH MULTIPLE RATES

In the above example, there was only one growth rate throughout the entire growth period, that is the constant annual increase of $2,000 over the first 25 years. More often than not in an actual planning study, the rate of growth may change, often between decades, during the growth period. The above procedure can still be used; however, some additional analysis is necessary. For example, consider the situation depicted in Figure XI-3 and described below.

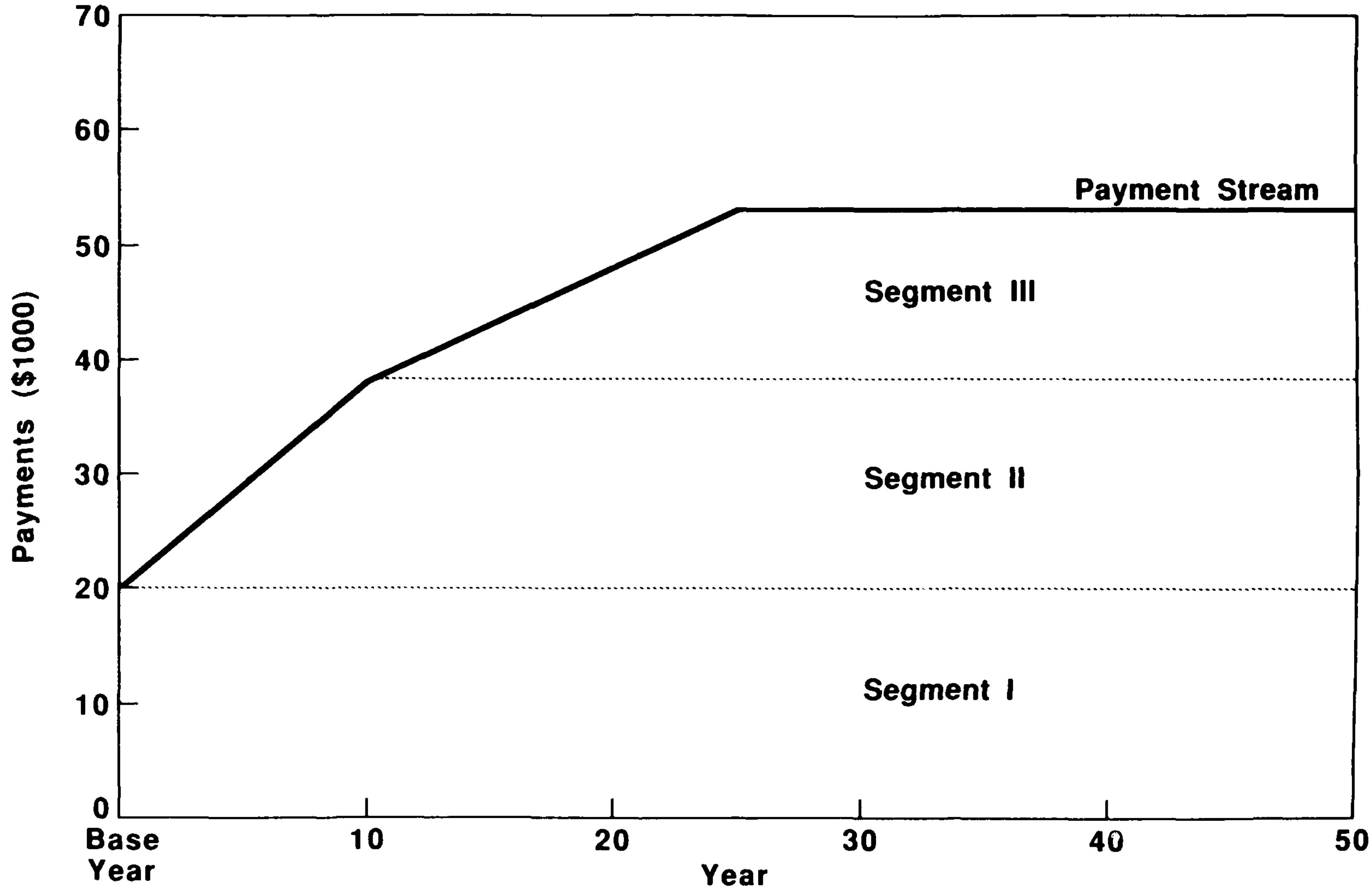

Figure XI-3. Example Straight Line Payment Stream with Multiple Growth Periods

EXAMPLE 6:

Period of analysis	= 50 years
Discount rate	= 8 percent
Incremental increases in payments per year	
Years 2-10	= $2,000
Years 11-25	= $1,000

Using the gradient series approach, the average annual value for each of the three segments of the payment stream depicted in Figure XI-3 are computed and then summed, to estimate the average annual value for the entire stream. The computational process is as follows:

Segment I: The derivation of the average annual value for Segment I is identical to that used in Example 5. That is, the average annual value of a constant payment stream of $20,000 per year throughout the period of analysis is $20,000.

Segment IIA&B: The present worth (in the base year) for Segment IIA is $51,960, determined by multiplying the gradient, ($2,000), by the present worth gradient series factor for 8 percent and 10 years, (25.98 from Equation 5). Segment IIB represents a constant payment stream of 40 years, (years 11 through 50). Remembering the end-of-accounting interval convention, (page XI-9), the amount of this payment stream is $19,000, that is the end-of-year 11 payment, ($39,000), less the constant payment of Segment I, ($20,000). The present worth (in the base year) of Segment IIB is then the constant payment, multiplied by the present worth of an annuity for 40 years from Equation 4, multiplied by the single payment present

worth factor for 10 years from Equation 2, or $104,950, ($19,000 x 11.925 x .4632). The sum of present values of Segment IIA, ($51,960), and Segment IIB, ($104,950), or $156,910, multiplied by the capital recovery factor, (.08174 from Equation 3), yields the average annual value of $12,826 for the combined Segment IIA&B.

Segment III A&B: The average annual value for Segment IIIA&B is somewhat similarly determined as for Segment IIA&B. The present worth (in the base year) of Segment IIIA is the amount of the gradient, (now $1,000), multiplied by the present worth of a gradient series factor for 15 years from Equation 5, multiplied by the single payment present worth factor for 10 years from Equation 2, or $22,183 ($1,000 x 47.89 x .4632). The amount of the constant payment of Segment IIIB is $14,000, that is the maximum annual payment ($53,000) less the sum of the constant payments from Segment I ($20,000) and Segment IIB ($19,000). The present worth (again, in the base year) of Segment IIIB is then the constant payment, multiplied by the present worth of an annuity for 25 years (from Equation 4), multiplied by the single payment present worth factor for 25 years (from Equation 2), or $21,820, ($14,000 x 10.675 x .1460). The sum of the present values of Segment IIIA ($22,183) and Segment IIIB ($21,820), or $44,003, multiplied by the capital recovery factor for 50 years (.08174 from Equation 3) yields the average annual value of $3,597 for the combined Segment IIIA&B.

The average annual value for the entire payment stream is then the sum of the average annual values from Segments I, IIA&B, and IIIA&B or, approximately, $36,400 ($20,000 + $12,826 + $3,597).

EXPONENTIAL GROWTH RATES

For many projects, future benefit and cost streams are projected to grow at exponential, rather than linear growth rates. As with linear growth projections, one method for determining the average annual value of a payment stream with an exponential growth component is to determine the present worth of each annual payment, sum the present worth of all payments, and amortize the total. An alternative procedure is available when the growth rate and period of growth are known. Consider the payment stream depicted in Figure XI-4 and summarized below.

EXAMPLE 7:

Period of analysis	= 50 years
Discount rate	= 8 percent
Initial (base year) payment	= $20,000
Growth rate per year	= 2 percent
Number of years in growth period	= 25

Somewhat similarly to the linear growth examples described above, the total payment stream is divided into segments for estimating the average annual value. A *cumulative present worth factor* (CPW) is used for estimating the average annual value for the growth period (Segment I), while the basic compound interest formulas, described at the beginning of this chapter, are used for the period where the payment is constant (Segment II).

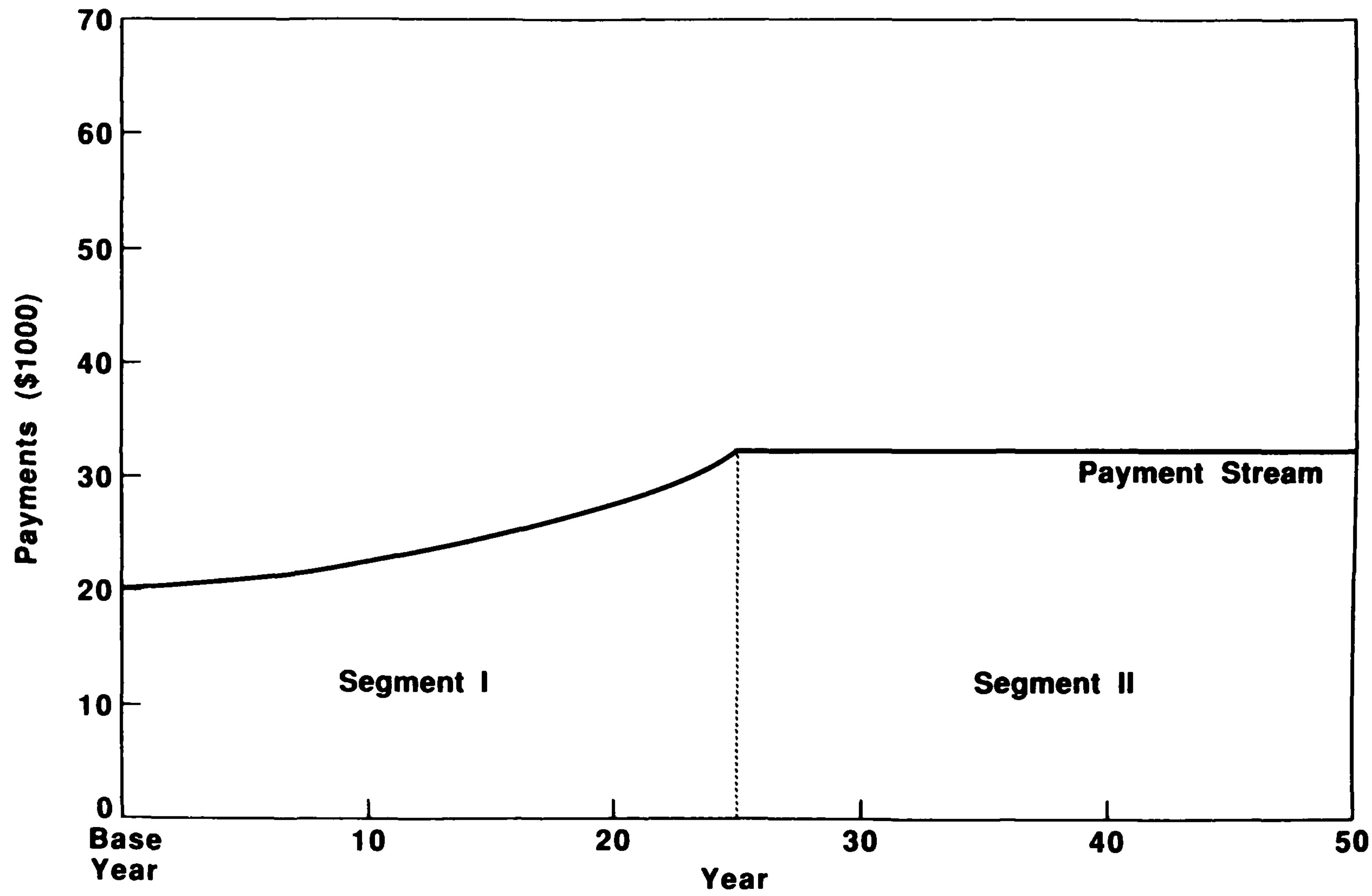

Figure XI-4. Example Exponential Payment Stream

Segment I: The cumulative present worth factor is:

$$CPW = \frac{((1 - (1 + k)^{-(n-1)})/k) + 1}{1 + i} \qquad (6)$$

where:

CPW = cumulative present worth, or the summation of all future discounted values in the growth period.

k = ((1 + i)/(1 + j)) - 1

i = discount rate (8% in this example)

j = growth rate (2% in this example)

n = number of years in the growth period (25 in this example)[4]

Solving Equation 6 for the example conditions yields a CPW factor of 12.6741. Multiplying this factor by the initial payment in the growth period yields the total cumulative present worth (at the beginning of the period) of all payments for that period. In this example, 12.6741 x $20,000, or $253,482 is the cumulative present worth, in the base year, of all payments for the years 1-25. The capital recovery factor, Equation 3, is then used to convert the cumulative present worth in the base year to an average annual value for the period of analysis ($253,482 x 0.08174 = $20,720).

Segment II: Segment II represents a constant annual payment over the remainder of the period of analysis, i.e. period of analysis less length of growth period(s). In this analysis, the constant payment is $32,200 and the remainder of the period of analysis is 25 years. The average annual value for this segment is computed similarly to Segment III in Example 6,

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[4]Again, the gradient series concept is used. The year 1 payment is $20,000. Payments then increase by two percent a year, beginning with the year 2 payment. The payment in year 25 is $20,000 x $(1.02)^{24}$.

except that the first step is not required. Multiplying the constant payment ($32,200), by the present worth of an annuity factor for 25 years (10.676 from Equation 4), yields the present worth of the segment at the end of year 25 ($343,767). Multiplying this value by the single payment present worth factor for 25 years (0.1460 from Equation 2), yields the present worth in the base year ($50,190). Finally, multiplying the present worth value by the capital recovery factor for 50 years (0.08174 from Equation 3) yields the average annual value ($4,102) for the period of analysis.

The sum of the average annual values from Segments I and II ($20,720 + $4,102) then yields the average annual value for the entire payment stream, (approximately $24,800 for this example). (Note: For this, as well as previous examples, it is not necessary to separately annualize the present value for each segment. The same result is obtained if the separate present values for each segment are first summed, and then the sum multiplied by the capital recovery factor.)

NEGATIVE GROWTH

The three previous examples were all based on increasing future trends. There can, of course, be declining trends. This topic will be addressed in less detail, however, since these cases are the exception, and since much of the previous discussion on growth curves still applies.

Negative straight line growth. Example 8 is, basically, the reverse of the situation depicted in Example 5. That is, an initial payment of $68,000 is received in the base year. Payments then decline by $2,000 per year until year 25 when they equal $20,000, and remain constant for the

remainder of the period of analysis. This payment stream is depicted in Figure XI-5.

EXAMPLE 8:

Period of analysis	= 50 years
Growth period	= 25 years
Discount rate	= 8%
Base year payment	= $20,000
Incremental decrease in payments per year	= $2,000

To compute the average annual value for the entire stream, estimates of the two Segments, I and II, are needed. As in Example 5, the estimate of Segment I is straightforward, the average annual value of a constant stream of payments of $20,000, is $20,000.

The approach to Segment II is less obvious, however, since this represents a declining, rather than an increasing, payment stream. It can be seen, however, that the sum of Segments II and III equal a constant payment stream ($68,000 - $20,000, or $48,000 in this example) throughout the period of analysis. In addition, Segment III can be treated as an increasing growth segment, increasing by $2,000 per year, from a payment of $0 in year 1, to $48,000 in year 25, and then remaining constant for the remainder of the period of analysis. Although graphically Segment III is an upside down version of Segment IIA&B in Figure XI-2, (Example 4), its average annual value is calculated exactly the same, and is also equal to $20,470. The average annual value of Segment II in Example 8 is then

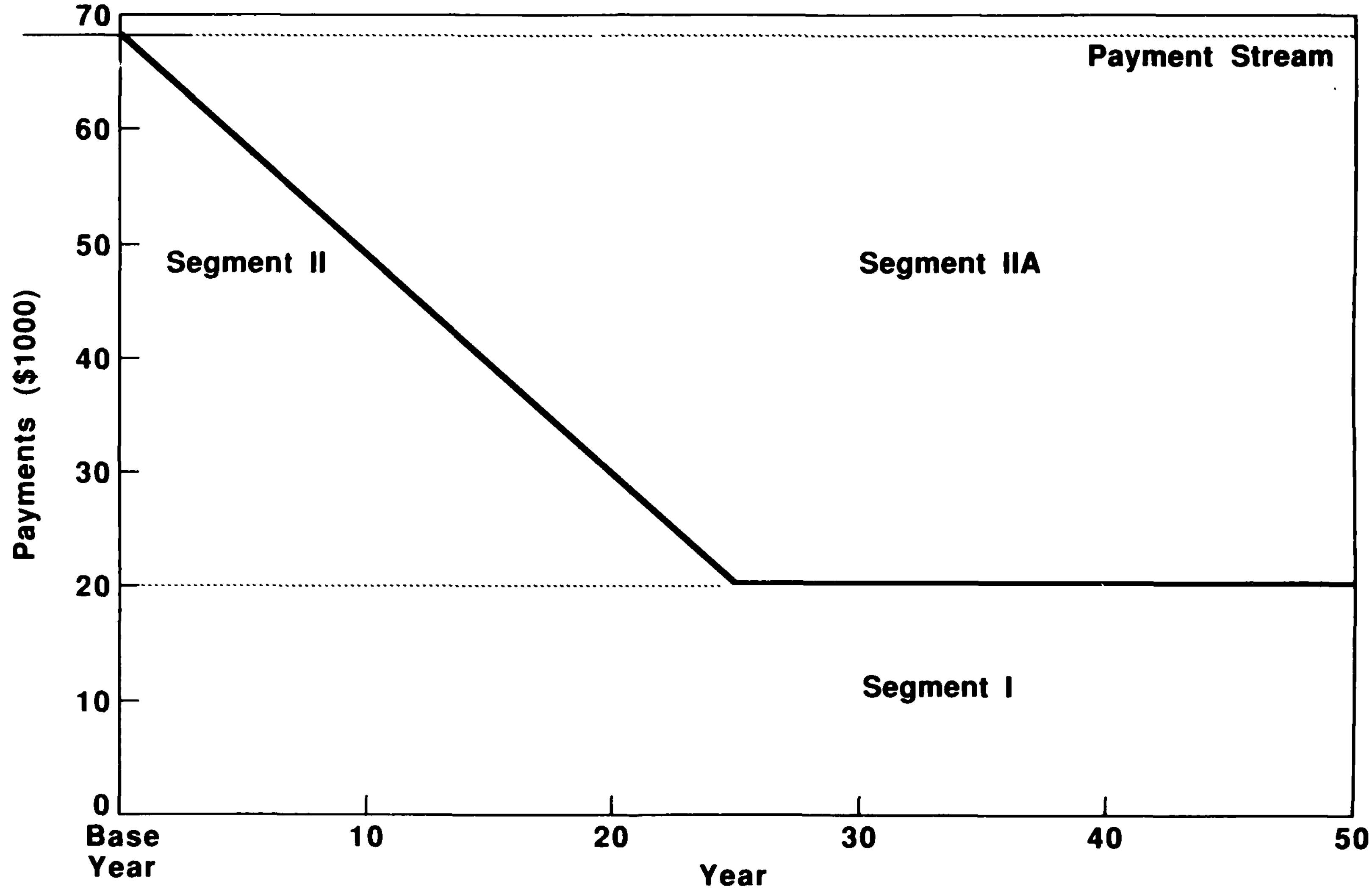

Figure XI-5. Example Straight Line Negative Growth Payment Stream

$48,000 - $20,470, or $27,530, and the total value of the payment stream is $47,530 ($20,000 from Segment I plus $27,530 from Segment II).

Negative exponential growth. To properly discount a trend that declines exponentially, it is first necessary to have an understanding of the derivation of a negative growth rate. The equation used for this computation is:

$$(1 - j)^{n-1} = T/B$$

Where:

T = terminal value or nth year value

B = base (year 1) value

j = growth rate

n = growth period in years (Note: Again the gradient series concept is used. That is, if there are n years in the growth period, (n - 1) increments of growth will occur.)

With a growth period of 10 years, and base and terminal values of 3,000 and 4,000, respectively, the computation of j is as follows:

$$(1 - j)^9 = 3000/4000 = .75$$

$$(1 - j) = (.75)^{1/9} = .9685$$

$$j = .9685 - 1 = -.0315$$

The annual rate of decline, is 3.15 percent, or j = -.0315 in this example. The formula for estimating the average annual value for an exponential growth period presented earlier, (Equation 6), can still be used when

addressing negative exponential growth; the negative growth rate is merely substituted for j, instead of a positive value.

SOME SPECIAL CASES

The planner will find it necessary to do discounting in certain situations that can be considered unique. These include benefits (or credits) for advanced bridge replacement, major replacement costs, periodic maintenance, and operation and maintenance (O&M) costs. Again, techniques developed previously are applicable to some of these cases, as discussed below.

Advanced bridge replacement. For many projects, relocations will result in the replacement of existing bridge facilities. Often the expected life of the replacement bridge will be greater than that of the existing structure, thereby extending the life of the bridge service being provided. Since the total cost of the new bridge is included in the first cost of the project, a credit for this extension is needed on the benefit side. A credit is also needed if any reduction in O&M costs will occur during the remaining life of the existing facility. Sample computations required to compute these benefits are presented in the following example and described below. All the interest factors used have been previously presented.

EXAMPLE 9: SAMPLE COMPUTATION OF BRIDGE REPLACEMENT BENEFITS

1.	Cost of new bridge	= $500,000
2.	Life of new bridge	= 50 years
3.	Remaining useful life of existing bridge	= 20 years
4.	Extension of bridge life (21st through 50th year)	= 30 years
5.	Annual O&M of existing bridge	= $5,000
6.	Annual O&M of new bridge	= $2,000
7.	Interest rate	= 8%
8.	Capital recovery factor (for 50 years)	= 0.08174
9.	Annual cost of new bridge = $500,000 x 0.08174	= $40,900
10.	Present worth of annuity factor for 30 years	= 11.258
11.	Benefits in year 20, credited to bridge life extension = $40,900 x 11.258	= $460,500
12.	Single payment present worth factor for 20 years	= 0.2145
13.	Present worth in year 1 of bridge extension = $460,500 x 0.2145	= $98,800
14.	Annual O&M savings (years 1-20) = $5,000 - $2,000	= $3,000
15.	Present worth of annuity factor for 20 years	= 9.818
16.	Present worth in year 1 of O&M savings = $3,000 x 9.818	= $29,500
17.	Present worth of total credit $98,800 + $29,500	= $128,300
18.	Average annual credit (benefit) = $128,300 x .08174	= $10,500

The first seven lines of Example 9 describe the basic conditions and values needed for the analysis. The basis for the credit for the extension of the useful life is that the replacement cost for the existing bridge will be deferred for 30 years. The annual credit for years 21-50 is assumed to be equal to the average annual value (cost) of the new bridge

for each of those years. This annual value (line 9) is estimated by multiplying the cost of the new bridge (line 1) by the capital recovery factor (line 8). The credit is a constant annuity in years 21-50. Its present worth in year 20 (line 11) is the amount of the annual annuity (line 9) multiplied by the present worth of an annuity for 30 years (line 10). The present worth in the base year (line 13), is then this value multiplied by the single payment, present worth factor for 20 years (line 12).

The estimated annual savings in O&M costs expected during the remaining useful life of the existing bridge are $3,000 (line 14). These annual savings would accrue during the first 20 years, and their present worth (line 16) is the product of the annual value and the present worth of an annuity for 20 years (line 15). The present worth of the total credit (line 17) is the sum of the present worth of the bridge extension credit (line 13) and annual O&M cost savings (line 16). The average annual value of the credit (line 18), is the present worth value multiplied by the capital recovery factor for 50 years (line 8).

Periodic Maintenance. Often project maintenance expenditures will occur at periodic intervals, rather than uniformly every year. In the following example, the project life is assumed to be 50 years with periodic maintenance expenditures of $75,000 required every 10 years. Note that no expenditures are included beyond the 40th year since any additional expenditures would cover a period beyond the project's life.

EXAMPLE 10: SAMPLE COMPUTATION FOR PERIODIC EXPENDITURES

1.	Life of project	= 50 years
2.	Expenditure cycle	= 10 years
3.	Discount rate	= 8%
4.	Periodic expenditure	= $75,000
5.	Present worth of 10th year value - single payment, present worth for 10 years, 0.4632 x $75,000	= $34,700
6.	Present worth of 20th year value - single payment, present worth for 20 years, 0.2145 x $75,000	= $16,100
7.	Present worth of 30th year value - single payment, present worth for 30 years, 0.0994 x $75,000	= $7,500
8.	Present worth of 40th year value - single payment, present worth for 40 years, 0.0460 x $75,000	= $3,500
9.	Total present worth - (5) + (6) + (7) + (8)	= $61,800
10.	Average annual value - capital recovery factor for 50 years, 0.08174 x $61,800	= $5,100

Major Replacement and Operation and Maintenance. If future replacement is a single event, the procedure for discounting is the same as that described for a single future payment in Example 3 above. If the future replacement is recurring, the procedure for discounting is the same as that just described for periodic expenditures in Example 10. Where operation and maintenance occurs annually and the value is constant, as is usually the case, the average annual value is equal to the constant O&M expense, as presented in Example 4.

Interest during construction. According to EP 1105-2-45, interest during construction (IDC) accounts for the cost of capital incurred during the construction period. The cost of a project to be amortized is the investment incurred up to the time that the project begins to produce

benefits, or the time when it is placed in operation. The investment cost at that time is the sum of construction and other initial costs plus interest during construction.

Costs incurred during the construction period should be increased by adding compound interest at the applicable project discount rate from the date the expenditures are incurred to the beginning of the period of analysis (base year). Interest on any additional expenditures incurred after the in-service date will be an operating expense. Following is an example of the calculation of IDC assuming uniform, end-of-month payments. The process is similar when using more typical, irregular monthly payments, (that is costs varying with the construction season or cycle), when using different accounting periods, (for example years rather than months), or when assuming a different timing of payments, (for example, costs being incurred at the middle, rather than the end of the month).

EXAMPLE 11: SAMPLE COMPUTATION FOR INTEREST DURING CONSTRUCTION

A: Input Data

1.	Construction period	= 2 years
2.	Total construction cost	= \$24,000,000
3.	Middle of month uniform payments = \$24,000,000/24	= \$1,000,000
4.	Annual interest rate	= 8 3/8%

B: Determination of Monthly Interest Rate

5. $(1 + i)^{12} = 1.08375$

$$1 + i = (1.08375)^{1/12}$$

$$i = .00672$$

C: IDC Computation

6. $$\text{IDC} = \sum_{m=1}^{n} P_m[(1 + i)^{n-1} - 1]$$

where:
n = number of periods, in months
P_m = the mth monthly payment
i = monthly interest rate

7.	IDC (from Table XI-1)	= \$1,949,000

TABLE XI-1
EXAMPLE IDC COMPUTATIONS

Month	Payment		Interest Factor		Interest
1	1,000,000	x	$[(1.00672)^{23}-1]$	=	$166,500
2	"	x	$[(1.00672)^{22}-1]$	=	158,800
3	"	x	$[(1.00672)^{21}-1]$	=	151,000
4	"	x	$[(1.00672)^{20}-1]$	=	143,300
5	"	x	$[(1.00672)^{19}-1]$	=	135,700
6	"	x	$[(1.00672)^{18}-1]$	=	128,100
7	"	x	$[(1.00672)^{17}-1]$	=	120,600
8	"	x	$[(1.00672)^{16}-1]$	=	113,100
9	"	x	$[(1.00672)^{15}-1]$	=	105,700
10	"	x	$[(1.00672)^{14}-1]$	=	98,300
11	"	x	$[(1.00672)^{13}-1]$	=	91,000
12	"	x	$[(1.00672)^{12}-1]$	=	83,700
13	"	x	$[(1.00672)^{11}-1]$	=	76,500
14	"	x	$[(1.00672)^{10}-1]$	=	69,300
15	"	x	$[(1.00672)^{9}-1]$	=	62,100
16	"	x	$[(1.00672)^{8}-1]$	=	55,000
17	"	x	$[(1.00672)^{7}-1]$	=	48,000
18	"	x	$[(1.00672)^{6}-1]$	=	41,000
19	"	x	$[(1.00672)^{5}-1]$	=	34,100
20	"	x	$[(1.00672)^{4}-1]$	=	27,200
21	"	x	$[(1.00672)^{3}-1]$	=	20,300
22	"	x	$[(1.00672)^{2}-1]$	=	13,500
23	"	x	$[(1.00672)^{1}-1]$	=	6,700
24	"	x	$[(1.00672)^{0}-1]$	=	0
Total --	24,000,000		--		$1,949,000

Again, the first four lines in Example 11 describe the basic conditions and values needed for the computations. In line 5, the monthly interest rate to be used in the computations is derived. Normally in financial analysis, the monthly rate is found by simply dividing the annual rate by twelve. For example, if the annual rate is 12 percent, the monthly rate is 12/12 or 1 percent. However, because of the cumulative nature of compounding, interest earned on 12 percent compounded monthly will be greater than on 12 percent compounded annually. The difference can be derived from equation 1, presented at the beginning of this chapter. The single payment, compound amount factor for an interest rate of 1 percent, compounded over 12 periods, is 1.1268, whereas the factor for an interest rate of 12 percent, compounded over one period is 1.1200. This stated annual rate of 12 percent is usually called the **nominal rate**, whereas the compounded rate of 12.68 percent is usually referred to as the **effective rate**.

Since the objective of benefit cost analysis is to compare all benefit and cost streams at the same annual discount rate, it is necessary for the IDC computations to find the interest rate that, compounded monthly, will yield an annual effective rate equal to the discount rate being used. This can be done by solving the equation provided at line 5.

Once the monthly rate to be used has been determined, the IDC can be computed. The equation at line 6 is for computing the total interest earned for n monthly installments at a rate of i. Solving this equation (Table XI-1), at an interest rate of 8 3/8 percent, for 24 monthly payments of $1,000,000, will yield the total interest earned, $1,949,000 in this example, at the time of the final payment. If the payments are assumed to

be incurred at the end of the month, then the final payment will usually occur concurrently with the beginning of the base year. The interest calculated with the equation at line 6 is then the total IDC. However, if some other timing of payments is assumed (e.g., EP 1105-2-45 suggests interest be computed from the middle of the month in which expenditures are incurred), then the additional interest that would be incurred between the timing of the final payment and the beginning of the base year may also (if significant) need to be calculated and included in the final estimate of IDC.

SUMMARY

The above examples have been presented to illustrate some of the basic discounting concepts and procedures that are often used in water resource development benefit-cost analysis. In order to clearly illustrate the concepts involved, lengthy hand calculations were sometimes used, (especially Example 11). Some short-cut techniques were presented that can reduce the computations required and, as indicated, closely approximate the estimates derived from more detailed, analytical approaches. These latter approaches, however, are readily adaptable to micro-computer spreadsheet and other software programs. Analysts are encouraged to use such programs. They are relatively easy to use, can minimize set-up and computational errors, and can easily incorporate changes in such factors as interest and growth rates and price levels.

CHAPTER XII

REPORT DOCUMENTATION GUIDELINES

The purpose of a feasibility report is to summarize the extent of the flood problem, present the possible solutions to the problem, and justify the basis for a recommended action or a no-project alternative. In presenting the project evaluation, there must be enough detail that a reviewer can ascertain the existing conditions and the projections that go into making the calculations.

The benefits of the recommended plan, the NED plan if it differs from the recommended plan, and any other plan carried through the planning process should be documented in the feasibility report.

The benefits of each plan should be displayed in current dollars for existing conditions and for conditions expected during the base year, and in ten year increments through 50 years beyond the base year. Conditions are usually assumed to remain constant after 50 years. Benefits for all years beyond the base year should be discounted by the administratively established rate.

Further guidelines for the contents of reports can be found in ER 1105-2-60, Planning Reports, 22 November 1985.

Feasibility reports with no recommended action. Feasibility reports that recommend no Federal action can be abbreviated in detail to show only the information needed to support the recommendations.

Reevaluation reports. When a new authorization or congressional post-authorization approval is required after a reevaluation is submitted, the conclusions should be documented to the same detail as the original

feasibility report. Otherwise, only an updating or reevaluation of the essential supporting information is required.

VERIFICATION OF BENEFITS

It is also of major importance to include tests or exercises for judging the validity of each measure. Several of those procedures are described below. There are at least five possible checks which can be performed to determine if benefits are reasonable and what difference there might be in the estimates of the net benefits or the benefit-cost ratio if any of the major assumptions were to change.

SENSITIVITY ANALYSIS

Sensitivity analysis is a valuable tool to substantiate an optimal solution when several variables are involved in a model. Planners can use sensitivity analysis to illustrate the range of values and conditions for which a project is justified, and how changes in the values of certain variables would affect which plan is recommended or the composition of the optimal project. The feasibility report should illustrate cases where the optimal plan is particularly sensitive to the ranges of values for any variable.

Sensitivity analysis should be applied to variables for which there is a particularly large degree of uncertainty. Confidence limits are an excellent tool for establishing the degree of uncertainty for any particular variable. Values are taken from both ends of each set

of confidence limits and used to recalculate benefits and compare them with the original estimates.

CONFIDENCE LIMITS FOR CRITICAL VARIABLES

Confidence limits will indicate, for selected degrees of certainty, the range of the actual values within which a variable would lie. As an example, Figure XII-1 indicates that there is a 95% probability that the true value of the elevation-frequency function lies within confidence bands shown in the illustration. In response to the requirement for more detailed analysis of risk and uncertainty, hydrologic analysis has begun including confidence limits for calculations of elevation-frequency relationships. Confidence limits can also be shown for structure value, content value, and depth damage relationships. Either 90 or 95% confidence limits are appropriate for most planning purposes. The size of confidence limits is determined by the extent of dispersion within the sample data.

AVERAGE STRUCTURE AND CONTENT VALUES

The average annual flood loss is compared with the structure value to determine if the estimated flood losses are reasonable. A very high damages-to-structure value ratio may indicate that annual flood damage estimates are too high. For example, it would be unreasonable to assume that a flood victim would continue to invest in a property that was receiving losses of greater than a stipulated percentage of the total structure value. An unreasonable damage-to-value ratio might also be due to inaccurate elevation-frequency data.

It is also useful to relate the estimated increase in structure and content damage to the estimated increases in the number of structures as well as structure and content values. Whenever increases in damages are based upon increases in value, a sensitivity analysis should be accomplished under alternate assumptions. The importance of changes in number of structures and the overall mix of structure types can also be changed in order to determine the effect of those changes on project benefits.

BREAK-EVEN YEARS

If a project's justification is dependent on future development, then the break-even year should be noted. The break-even year is the year that benefits from future bring the benefit-cost ratio to above 1.0. Break-even years can be expressed for benefits computed in undiscounted or discounted dollars.

INTERNAL RATE OF RETURN

The internal rate of return is the interest rate for which benefits equal cost when benefits are discounted over the period of analysis.

DISCOUNT RATE

The discount rate for project justification is locked in when a project is authorized. In evaluating already authorized projects, the effect of using the current discount rate should be illustrated.

APPENDICES

APPENDIX A

INSTITUTIONAL SETTING

STATUTORY SETTING

Federal responsibility in flood mitigation activities was established by legislation over a period of many years, with initial efforts in the Lower Mississippi River Valley. The most influential legislation and Executive Orders are described below:

1) The Mississippi River Commission, 1879, (Public Law 46-34), established the Corps of Engineers' role in flood control activity, with the formation of the Mississippi River Commission to consider flood problems in the Lower Mississippi Valley. From 1879 to 1917, the Commission's role was limited to hydrologic surveys and the raising and repair of existing levees as they related to channel conditions. The original authorization was extended to the headwaters of the Mississippi River. Today, the MRC jurisdiction covers the main stem of the Mississippi and major portions of its tributaries from Cape Girardeau, Missouri, to the Gulf of Mexico.

2) The Flood Control Act of 1917 (Public Law 64-367), authorized the first flood control construction outside the Mississippi Valley. The 1917 Act also opened the door for multi-purpose, basin-wide planning. The Act stated that flood control should be considered in comprehensive watershed studies, along with navigation and hydropower. 3) The Flood Control Act of 1928 (Public Law 70-391), authorized comprehensive flood control program for the Mississippi River and its tributaries.

4) The Flood Control Act of 1936 (Public Law 74-738). established the Corps of Engineers' flood control role as a National program. A comprehensive program of planning, designing, and building structural flood control works was undertaken. The 1936 Act established cost-benefit analysis as the principal tool for evaluating the efficiency of any flood control project. The 1936 Act set a precedent for using cost-benefit analysis for evaluating all other major Federal water resource projects and many other public works programs. Federal interest was defined as extending to all navigable waters and their tributaries. The 1936 Act also gave the Corps the primary Federal responsibility for flood control.

5) The Flood Control Act of 1944, (Public Law 78-534). clarified that "flood control" meant major drainage improvements. This was to make a distinction between the flood control activities of the Corps and the small drainage area activities of the Soil Conservation Service.

6) The Flood Control Act of 1948, (Public Law 80-858). provides the continuing authority for small flood control activities. Section 205 authorized the construction of small flood control projects that had not been specifically authorized by Congress. A Federal expenditure limit was placed on each project as well as the program funds allotted per fiscal year. The current limit is $5 million per project, as set by the Water Resources Development Act of 1986 (Public Law 99-662).

7) The National Flood Insurance Act of 1968, (Public Law 90-448). established the National Flood Insurance Program. This law was passed in response to recommendations of the Presidential Task Force on Flood Control Report, "House Document 465." Subsidized flood insurance was made available to floodplain occupants. Section 1314 discouraged other

Federal disaster assistance for non-participating communities. Section 1315 required participating communities to enact land use controls to discourage future floodplain development.

8) The National Environmental Policy Act of 1969 (NEPA), (Public Law 91-190), requires an environmental impact statement be prepared for any action involving Federal construction, funding, or approval that may "significantly affect the quality of the human environment". Federal agencies are required to thoroughly investigate the consequences of any recommended actions and alternatives. Federal actions may be curtailed unless an adequate environmental impact statement has been prepared.

9) The River and Harbor Act of 1970, (Public Law 91-611), broadened the evaluation criteria to include regional economic development, environmental quality, and social well-being (now known as other social effects). From that point on, it was required that all Federal water resource projects be evaluated using these accounts.

10) The Flood Disaster Protection Act of 1973, Public Law 93-234, amended the 1968 Act that established the National Flood Insurance Program. It requires states and communities, as a condition for receiving Federal aid, to prohibit development in floodways, and to ensure the first floor elevation of all future residential development is at or above the one-percent flood level, and that the first floor of all non-residential development is above or floodproofed to above the one-percent flood. The law also requires that no substantial (greater than 50 percent of the pre-flood value) improvement or repair be made to a structure located below the one-percent flood level.

11) The Water Resource Development Act of 1974, Public Law 93-251, Section 73, requires consideration be given to nonstructural alternatives for flood damage prevention or reduction. Subsequent actions have enlarged the scope of the Federal interest to include consideration of all alternatives in controlling flood waters, reducing the susceptibility of property to flood damage, and relieving human and financial losses. The encompassing term for these activities is "floodplain management."

12) The Water Resource Development Act of 1986, Public Law 99-662, established the requirement of 50-50 cost-sharing for feasibility studies. Fifty percent of the local share can be contributed through in-kind services. The Act requires that at least 25% and no more than 50% of project costs be paid by the local sponsor. At least 5% of the project costs are required during construction. There are provisions in the Act to reduce the requirements for certain localities and states where there would be difficulty in meeting the local cost sharing requirements.

13) Executive Order 11988, Floodplain Management, requires all concerned Federal agencies to provide leadership and take action to : 1) avoid development in the (100-year) floodplain unless it is the only practicable alternative; 2) reduce the hazards and risk associated with floods; 3) minimize the impact of floods on human safety, health and welfare; and, 4) restore and preserve the natural and beneficial values on the floodplain. The intent is to ensure Corps' projects do not encourage unwise floodplain development.

14) Executive Order 11990, 24 May 1977, Protection of Wetlands, requires Federal agencies to provide leadership in minimizing the destruction or degradation of wetlands. Section Two of this order states

that, in furtherance of the National Environmental Policy Act of 1969, agencies shall avoid undertaking or assisting in new construction located in wetlands unless there is no practical alternative. This Executive Order was issued to make Federal agency programs consistent with Section 404 of the Water Pollution Control Act Amendments of 1972, Public Law 92-500.

AGENCY SETTING

This section defines the role of Federal agencies in managing the Nation's flood problems. The description is included to provide a background into the coordination activities that are important, the resources that are available, and additional responsibilities the Corps might have in dealing with other agencies. The major responsibilities of each agency for various aspects of flood damage reduction are given in Table A-1. Corps' economists and planners are encouraged, and in many cases have the responsibility, to contact other agencies listed below.

DEPARTMENT OF AGRICULTURE

Agricultural Stabilization and Conservation Service (ASCS).

ASCS manages the Agriculture Department's surplus grain program, and is responsible for emergency food supplies in the case of a natural emergency. ASCS administers assistance to rural areas for Presidential Disaster Declarations. The agency also provides technical assistance and incentives for floodplain areas and wetlands to go uncultivated.

TABLE A-1
FEDERAL FLOOD LOSS REDUCTION
PROGRAM BY AGENCY

Program / Agency	Department of Agriculture					Department of Commerce			Department of Defense	Department of Energy	Department of Housing and Urban Development	Department of the Interior				Department of Transportation		Federal Emergency Management Agency			
	Agricultural Stabilization and Conservation Service	Economic Research Service	Farmers Home Administration	Forest Service	Soil Conservation Service	Bureau of Economic Analysis	Economic Development Administration	National Weather Service	Army Corps of Engineers	Federal Energy Regulatory Commission	Community Planning and Development	Bureau of Land Management	Bureau of Reclamation	Fish and Wildlife Service	Geological Survey	Coast Guard	Federal Highway Administration	Federal Insurance Administration	State and Local Programs and Support Directorate	Small Business Administration	Tennessee Valley Authority
*Flood Insurance Studies**	-	-	-	-	*	-	-	-	*	-	-	-	-	-	*	-	-	S	-	-	*
Flood Plain Management Services	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	S	-	-	S
Flood Plain Information Studies and Reports																					
Riverine	-	-	-	-	S	-	-	-	S	-	-	-	-	S	S	-	-	F	-	-	S
Coastal	-	-	-	-	I	G	-	-	S	-	-	-	-	S	I	-	-	F	-	-	-
Technical and Planning Services**																					
Full Program	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	F	-	-	S
Program Elements	-	I	G	I	S	I	S	S	S	I	-	I	I	-	S	-	I	-	I	-	S
Flood Modifying Construction	-	-	G	I	S	-	F	-	S	-	-	-	-	-	S	-	-	-	F	-	S
Flood Preparedness, Emergency, and Recovery	F	-	G	S	S	G	-	-	S	-	G	-	-	-	S	S	-	G	GS	G	-
Warning and Forecasting	-	-	-	-	-	S	-	-	S	-	-	-	-	-	S	-	-	-	I	-	-
Research	-	S	-	I	I	S	S	-	S	-	-	-	S	S	S	-	-	-	-	-	-
Open Space	-	-	-	I	S	G	-	-	-	-	G	-	-	S	-	-	-	I	-	-	-

*Adminstered by the Federal Insurance Administration through reimbursable technical studies by agency shown.
**Land and Water Resources.

S Staff and Funds
F Funds
G Grants and Loans
I Incidental

Adapted from Federal Emergency Management Agency, A Unified Program for Floodplain Management, FEMA 100, Washington, D.C.: Federal Emergency Management Agency, 1986.

Economic Research Service (ERS). ERS monitors and projects agricultural production and other economic activities in rural areas.

Farmers Home Administration (FmHA). FMHA makes post-disaster loans to eligible, family-size farms, ranches and aquafarms. The size of loans are limited to 80% of the total loss and by absolute dollar amount. Rates are graduated, with a below market rate on the first $100,000.

Forest Service. The Forest Service owns vast holdings of forested land throughout the United States and manages considerable land that is owned privately or by another unit of government but within Forest Service boundaries. Part of this management responsibility is provision for flood control and land use management.

Soil Conservation Service. The Soil Conservation Service was established as part of the Department of Agriculture under the 1935 Soil Conservation Act for the purpose of managing a national soil conservation program. The original authority limited SCS activity to 11 watersheds. This authority was expanded under the Watershed Protection and Flood Prevention Act (PL 83-566) to cover all watersheds in the country of 250,000 acres or less. The acre limitation was established under interagency agreement signed with the Corps of Engineers on September 23, 1963. With respect to flood protection by engineering works, the authority included any flood control and drainage works which could be built for $250,000 or less, and with detention structures with capacities of 12,500 acre-feet or less. Any plan that exceeds the limitations stated above can still be undertaken by the SCS under project specific authority.

Although the great percentage of SCS work is in rural areas, the agency authority and mission does extend to some urbanized areas.

Particularly important are the conservation and storm drainage technical assistance programs, which do a great deal to prevent flood problems from occurring. To the extent that any Corps' project might involve these practices and the construction of small detention structures, the work of the SCS is particularly relevant to Corps' planning and benefit assessment.

DEPARTMENT OF COMMERCE

Bureau of Economic Analysis (BEA). BEA is responsible for maintaining population, income, and employment projections for states and Standard Metropolitan Statistical Areas (SMSA). The Bureau provides additional indicators of economic activity and economic structure for BEA regions defined by economic interdependence. These include regional multipliers and input-output tables. The Bureau publishes price indexes and other economic data, monthly in the Survey of Current Business.

Economic Development Administration (EDA). EDA issues grants and loan guarantees in communities with chronic unemployment. This financial assistance can be used for flood control and drainage structures.

National Weather Service (NWS). The National Weather Service is part of the National Oceanic and Atmospheric Administration of the Commerce Department.

The Weather Service has the prime responsibility for keeping records of climatological data, records of flood damages, and issuing flood warnings throughout the United States. The Weather Service became part of the Commerce Department in 1940. Weather information has been considered vital to the operation of many businesses. Weather Service climatological

data includes rainfall records, and stream gage readings. NWS flood damage records are the most geographically comprehensive available. However, information is collected mainly from secondary sources, and does not get site specific. NWS also keeps records of deaths and serious injuries caused by flood events. The NWS report, Climatological Data in the United States, which contains weather and flood damage information, was published monthly and annually until 1979. More recent information can be obtained from the Weather Service Office on climatological data and the Annual Flood Damage Report, published by the Office of the Chief of Engineers, Hydraulics and Hydrology Division, Water Control/Quality Branch.

DEPARTMENT OF DEFENSE

Army Corps of Engineers. The Corps of Engineers has responsibility for providing flood protection where economically justified, environmentally sound, and publicly acceptable. The Corps' jurisdiction in flood damage alleviation is on navigable waterways and their tributaries in drainage watersheds of at least 250,000 acres. The Corps also provides emergency disaster assistance to flooded areas, inspection of flood control structures, repair of damaged structures, preparation and interpretation of floodplain maps, preparation of flood forecasting and response plans, installation of flood forecasting equipment, permanent relocation, and floodproofing.

DEPARTMENT OF ENERGY

Federal Energy Regulatory Commission (FERC). FERC licenses hydroelectric facilities, and therefore has a strong interest in dam safety.

DEVELOPMENT OF HOUSING AND URBAN (HUD)

Community Planning and Development. This office of HUD offers Community Development Block Grants to communities for public facilities and to improve living conditions for urban residents. Block grants can be used to control flooding and drainage problems and for relocation. The Community Planning and Development Office insures compliance with the Uniform Relocation Assistance Act of 1974 (P.L. 88-633). The act provides that when Federal funds are used for relocation, the relocated individuals must be moved to "decent, safe, and sanitary" housing and that these individuals are provided adequate funds to cover moving and incidental costs for the relocation.

DEPARTMENT OF INTERIOR

Bureau of Land Management. The Bureau of Land Management is responsible for land use planning and control of flooding and drainage problems, where needed, in the agency's vast land holdings.

Bureau of Reclamation. The Bureau of Reclamation was established as part of the U.S. Geological Survey (U.S.G.S.) under the Reclamation Act of 1902, and was separated from the U.S.G.S. in 1907. The Bureau's original jurisdiction covered 17 western states with the purpose of water reclamation for irrigation. Hydroelectric power generation, flood

control, soil conservation, recreation, and fish and wildlife conservation have been added to its role, and the Bureau's mission and procedures are very similar to the Corps'. Planning and economic analysis responsibilities for flood control works are done under interagency agreement with the Corps. Corps' districts doing flood control works on Bureau projects are subject to the same regulations and guidelines as they would be on a Corps' project.

Fish and Wildlife Service. The Fish and Wildlife Service participates in writing and review of environmental impact statements and environmental mitigation plans so that flood damage reduction measures can be implemented with minimal harm to fish and wildlife habitats, and particularly the habitats of endangered species.

Geological Survey (USGS). The Geological Survey collects, maintains, and interprets considerable data on water resources, topography, and other physical features that are important for use in Corps' flood control studies. The USGS topographic maps cover the entire country at varying dates and detail.

USGS satellites and aerial photos can be used to create more detailed and up-to-date maps than currently exist. The agency maintains a long history of stream gage records for many parts of the country.

DEPARTMENT OF TRANSPORTATION

Coast Guard. The Coast Guard participates in search and rescue for people endangered by floodwater and hurricanes.

Federal Highway Administration. The Highway Administration offers technical assistance to help build roads which are free of floods and other hazards.

INDEPENDENT AGENCIES

INTERNATIONAL BOUNDARY AND WATER COMMISSION

This commission is responsible for carrying out treaties and other agreements between the United States and Mexico. Part of the Commission's responsibility is to manage flooding problems on the Rio Grande and other boundary rivers.

FEDERAL EMERGENCY MANAGEMENT AGENCY (FEMA)

National Emergency Training Center. This center, in Emmitsburg, Maryland, offers programs for Federal, state, and local personnel in hazard mitigation, emergency preparedness, disaster response and long term recovery.

Federal Insurance Administration (FIA). FIA administers the National Flood Insurance Program. As part of that program, the agency produces maps of floodplains and floodways, sets requirements for building regulations used by participating communities, and maintains a file of more than 300,000 flood damage claims that it has processed since the agency was established.

State and Local Programs Directorate. This office administers disaster relief to communities after floods. The State and Local Programs Directorate administers the financial support that is allocated after

Presidential Disaster Declarations. Technical assistance is provided through interagency hazard mitigation team reports which are issued following the Declarations.

SMALL BUSINESS ADMINISTRATION (SBA)

The SBA makes loans to flood victims so they may repair, rebuild, or replace homes, businesses, and other property.

TENNESSEE VALLEY AUTHORITY (TVA)

The Tennessee Valley Authority (TVA) was created by Congress in 1933 with the primary objective of bringing economic development to a depressed region. TVA was given many broad powers for public works construction and operation which have primarily centered around water resource development and electric power generation. TVA has built substantial flood control works and offered assistance to state and local governments in creating their own local protection service. TVA has done a great deal of research and development of nonstructural flood alleviation measures.

APPENDIX B

ANNOTATED REFERENCES

There is a vast literature of procedures, data sources, theory, and examples of how flood alleviation plans can be evaluated. This chapter provides an annotated listing of some of the more useful sources of information. These include Corps of Engineers' regulations, computer programs, data sources, research reports, and economic and engineering technical literature.

CORPS OF ENGINEERS' PLANNING GUIDANCE

In a move to centralize and simplify the regulations that Corps' planners have to follow, all of the critical planning guidance was consolidated into the Planning Guidance Notebook. The notebook presently consists of Principles and Guidelines and other Engineering Regulations (ERs). The engineering regulations give the procedures that are generally followed in conducting and documenting feasibility reports. Since everything in the Planning Guidance Notebook is considered "guidance", there is no requirement that procedures be followed exactly as they are written. However, whenever significant deviations are made from this guidance, the reasons should be well documented.

Engineering Pamphlets are basic references to suggested procedures which can be used in the planning process. Engineering Pamphlets have no force of regulation.

Engineering Circulars (ECs) are also included in the Planning Guidance Notebook. The ECs are effective for a period not to exceed one year. The ECs are often adopted in some form as a new ER or a change in an existing one.

The following engineering regulations and engineering pamphlets were in effect at the time of this writing. Dates are given for the original release of the regulation. An up-to-date copy of the Planning Guidance Notebook should have all the changes issued for each regulation.

ER 1105-2-10. Planning Programs. 18 December 1985

1) This regulation provides planning guidance and management responsibility for feasibility and preconstruction reports, changes to uncompleted authorized projects, deauthorization of projects, continuing authorities, floodplain management services, and planning assistance to states. There is information that may be useful in determining the level of detail and format for various types of reports.

2) EP 1105-2-15. Planning Programs. 15 November 1985. This Engineering Pamphlet has additional information on the review process for Continuing Authorities. There is a description of the Floodplain Management Services Program (FPMS) and technical services offered by the Corps.

3) ER 1105-2-20. Project Purpose Planning Guidance. 15 May 1985. The Federal interest, general policies and specific guidance is given for all of the major Corps' planning missions. This ER defines structural and nonstructural measures and project standards, such as the freeboard requirement. Hydrologic frequency terminology is defined. The application of risk and uncertainty to the evaluation process is given.

4) ER 1105-2-30. General Planning Principles, 18 October 1985. This report is the introductory section of P & G. Many of the basic planning concepts applicable to all project purposes are defined. The NED account is described in detail along with the three other evaluation accounts; environmental quality, regional economic development, and other social effects. The six stages of the planning process are described.

5) ER 1105-2-40. Economic Considerations, 23 December 1983. This ER contains the procedures for calculating and displaying the NED benefits for each Federal water resource program. The benefit categories are described. The applicability of each benefit category is defined. The steps in calculating the benefits for each type of project are given.

6) EP 1105-2-45. Economic Considerations, 11 January 1982. This EP supplements P & G with an explanation of the most important tools used in the evaluation of benefits. Particularly relevant sections are on discounting methods, economic base studies, and and sampling procedures.

7) ER 1105-2-60. Planning Reports, 22 November 1985. The organization and content of various types of planning reports are described.

8) Fiscal Year Reference Handbook. The Reference Handbook is published annually as an Engineering Circular (EC). It contains updated information on important parameters used in economic evaluation, such as the official discount rate, National Flood Insurance Program operating costs (used directly as a benefit for property taken out of the one percent floodplain), and communities eligible for employment benefits.

DATA SOURCES

1) U. S. Census. A summary of U.S. Census Bureau data available in publications, microfilm, on mainframe-computer, and micro-computer is published in the annual publication, Census Catalog and Guide, Washington, D.C.: U.S. Department of Commerce, Census Bureau.

2) SEEDIS. SEEDIS is an on-line demographic data base that is available to all Corps' districts. SEEDIS contains the most detailed and up-to-date census information. Retrieval of specific information can be obtained through direct computer access or with the assistance of the Lawrence Berkeley Laboratories, Berkeley, California. An annual contract, maintained by the Institute for Water Resources, allows access and retrieval of SEEDIS information.

3) Environmental Technical Information System (ETIS). This is a series of computer data bases, data base management routines, and statistical analysis procedures for nationwide socio-economic data. The ETIS system was developed by the Corps of Engineers' Construction Engineering Research Laboratory and is now administered by the Department of Urban and Regional Planning at the University of Illinois in Champaign-Urbana. An overview of the system can be found in the publication ETIS and its Subsystems, 1986. The Economic Impact Forecast System (EIFS) can draw on the most recent census statistics and estimates and supplementary information from other agencies, such as the Bureau of Economic Analysis and Bureau of Labor Statistics, for making breakdowns and reports of socio-economic information and for executing a number of statistical operations.

4) Marshall-Swift Company. Marshall Valuation Service, Los Angeles, published annually. Marshall-Swift has an on-line data base and annually updated reference to calculate the depreciated replacement value of nearly any type of building.

5) U.S. Department of Commerce, Bureau of Economic Analysis (BEA). OBERS BEA Regional Projections, Volumes 1 and 2 are published every five years. OBERS include historical data and projections at five year intervals for each state and standard metropolitan statistical area. Data are included on population, income, earnings, and employment. "OBERS" stands for Office of Business Economics (now BEA) and the U.S. Department of Agriculture, Economic Research Service. OBERS is now the sole responsibility of BEA.

BENEFIT CALCULATION COMPUTER PROGRAMS

There are at least 20 computer programs used in the calculation of flood damage and flood damage reduction benefits, which have been developed by the Hydrologic Engineering Center and Corps district and division offices. There are programs applicable to most types of flooding situations. These programs are set up to run on nearly any kind of mainframe, mini, or microcomputer in use within the Corps. Some of the more widely used programs are listed below:

Hydrologic Engineering Center (HEC) Programs

Expected Annual Damages (EAD). EAD is the most widely used flood damage calculation program within the Corps. It runs on either micro or mini-computers. It computes expected annual damages by flood reach, given the basic and or derived relationships used in damage calculation. (See EAD User's Manual, Davis, California: Hydrologic Engineering Center, 1984.)

Structure Inventory for Damage Analysis (SID). SID is used along with EAD for economic inventory data. SID is used for calculating elevation-damage relationships. (See SID User's Manual, Davis: HEC, 1982.)

Hydrologic Engineering Center Data Storage System (HECDSS). HECDSS is written to store and manipulate data used by various other HEC computer programs. HECDSS operates on the Harris Minicomputer and is being made to run on the IBM-PC. (See HECDSS User's Guide and Utility Program Manuals, Davis: HEC, 1986.)

Some Corps' District Programs

STDMA. STDMA is a Fort Worth District program used to calculate expected annual damages and damages by individual events. It has the advantage of calculating damage for particular properties by river mile location. It operates on the Harris mini-computer and the IBM-PC. STDMA is well documented in unpublished district reports.

Average Annual Damage Program (URBAN). Urban is a New Orleans District program that calculates expected annual damages, depth-damage functions, and damage frequency curves. It runs on either the Honeywell

mainframe, Harris mini-computer, or the IBM-PC. The program has a variety of output formats. It is documented in unpublished district material.

Depth-Damage System (DDS). DDS is a versatile St. Paul District program that is used to compute depth-damage functions, damage-frequency curves, and emergency costs. Data can be entered on an IBM-PC with D-Base III, and the program is run on the Harris. The program is documented in an unpublished district report.

ECONOMIC AND ENGINEERING TECHNICAL LITERATURE

1. Periodicals

Water Resources Research, published monthly by the American Geophysical Union. This journal publishes a broad range of technical literature on water resource planning and analysis. There is a heavy concentration on theoretical background and quantitative analysis.

Water Resources Bulletin, published bimonthly by the American Water Resources Association. This journal has articles on water resource planning, hydrology and hydraulics, meterological, institutional, sociological, and economics. Reviews of many books on water resources and information on water legislation and policies are given.

Journal of Economic Literature, published quarterly by the American Economics Association. This journal gives reviews or annotated listings of newly published books on economics. It contains an exhaustive listing of current articles on economics.

Journal of Water Resources Planning and Management, published quarterly by the American Society of Civil Engineers (ASCE). This is part of a series of ASCE division journals and the journal most directly applicable flood damage analysis.

2. Books

Babbie, Earl R. The Practice of Social Research, Belmont, California: Wadsworth Publishing Company, 1979. This basic text gives a detailed look at the theoretical and common sense of survey design. There is discussion on how to design questionnaires and sampling procedures, how questionnaires should be administered, and how results should be interpreted.

Box, George E. P., William G. Hunter, and J. Stuart Hunter. Statistics for Experiments: An Introduction to Design, Data Analysis, and Model Building, New York: John Wiley and Sons, 1978. This is a general text on statistical experimentation. There is considerable information on sampling methods and probability distributions.

Eckstein, Otto. Water Resource Development: The Economics of Project Evaluation, Cambridge, Massachusetts: Harvard University Press, 1958.

Grant, Eugene L., W. Grant Ireson, and Richard S. Leavenworth. Principles of Engineering Economy, 7th edition, New York: John Wiley and Sons, New York, 1982.

James, L. Douglas and Robert E. Lee. Economics of Water Resources Planning, New York: McGraw-Hill, 1972.

Kates, Robert W. Industrial Flood Losses: Damage Estimation in the Leheigh Valley, Chicago: University of Chicago, 1965. This is a thorough study of industrial physical and income losses in the Leheigh Valley of Eastern Pennsylvania. "Synthetic" estimates are made for hypothetical flood levels.

Kelejian, Harry H. and Wallace E. Oates. Introduction to Econometrics: Principles and Applications, New York: Harper and Row, 1981. This is a straight-forward text on regression analysis, on formulating models, interpreting results, and staying clear of potential problems.

Maas, Arthur. Water Research, edited by Allen V. Kneese and Stephen C. Smith, Baltimore: Johns Hopkins University Press, 1965.

Mishan, Edward J. Cost-Benefit Analysis, New York: Praeger Publishers, 1976. Mishan's book is a discussion of the principal issues in cost-benefit analysis. An analytic framework based on these issues is drawn from welfare economics, public finance, and micro-economic theory. Illustrations are given for a variety of projects, illustrating and evaluating various ways to treat the many problems encountered in cost-benefit analysis.

Penning-Rowsell, Edmund C. and John B. Chatterton. The Benefits of Flood Alleviation: A Manual of Assessment Techniques, Westmead, England: Saxon House, 1977. This comprehensive manual of flood benefit calculation covers the many considerations in analyzing benefit for various types of properties. The manual is well illustrated with case studies and a good deal of specific information on the susceptibility and depth-damage relationships.

Pindyck, Robert S. and Daniel L. Rubinfeld. Econometric Models and Economic Forecast. This is an advanced text in econometric modeling theory and procedures.

Sheaffer, John R. Flood Proofing: An Element in a Flood Damage Reduction Program, Chicago: University of Chicago, 1960.

Smith, Gerald W. Engineering Economy: Analysis of Capital Expenditures, Ames, Iowa: Iowa State University Press, 1973.

Steinberg, Bory. Flood Damage Prevention Services of the U.S. Army Corps of Engineers: An Evaluation of Policy Changes and Program Outcomes During 1970-1983, Measured Against Criteria of Equity, Efficiency, and Responsiveness, Dissertation 84-D-2, Fort Belvoir, Va.: U.S. Army Corps of Engineers, Institute for Water Resources, 1984.

White, Gilbert F. Choice of Adjustment to Floods, Chicago: University of Chicago, 1964.

RESEARCH AND TECHNICAL REPORTS

Burnham, Michael, William K. Johnson, and Darryl Davis. Hydrologic Engineering in Planning, Davis, California: U.S. Army Corps of Engineers Hydrologic Engineering Center, 1981. This training manual provides concise, understandable, and informative explanations of the fundamental principles of hydrology and their application.

Davis, Stuart A. Business Depth-Damage Analysis Procedures, Ft. Belvoir, Virginia: U.S. Army Corps of Engineers, Institute for Water Resources, 1985. This report reviews procedures used in all Corps of Engineer Districts and in other agencies for establishing depth-damage relationships for commercial, industrial, and institutional property.

Eddin, Shehab and Larry Montgomery. Flood Damage Report for Frankfort, Kentucky, Louisville: U.S. Army Engineer District, Louisville, 1981. This is an intensive study of physical and non-physical flood losses from the 1981 flood in Frankfort. This report is unique for its coverage of non-physical costs. The procedures and findings of the study are well documented.

Johnson, William K. Physical and Economic Feasibility of Nonstructural Flood Plain Management Measures, Davis, California: U.S. Army Corps of Engineers, Hydrologic Engineering Center, and Fort Belvoir, Va.: U.S. Army Corps of Engineers, Institute for Water Resources, 1978.

Moser, David A. Assessment of the Economic Benefits from Flood Damage Mitigation by Relocation and Evacuation, Ft. Belvoir, Virginia: U.S. Army Corps of Engineers, Institute for Water Resources, Research Report 85-R-1, 1985.

U.S. Inter-Agency Committee on Water Resources, Subcommittee on Evaluation Standards. Proposed Practices for Economic Analysis of River Basin Projects (the Green Book), Washington, 1958.

APPENDIX C

GLOSSARY

Affected Area: the area affected by a proposed plan is the floodplain plus other areas likely to serve as alternate sites for activities which might use the floodplain if it were protected.

Affluence Factor: the effect of increasing per capita income on the unit value of residential contents, and consequently to the content-to-structure value ratio for the existing housing stock.

Authorized Project: when the recommended plan is included in an enacted omnibus bill, it is said to be "authorized." However, it may never be constructed. Congress must approve funds, by a separate act, for post-authorization studies.

Average Annual Equivalent Damage: The present annualized value of all expected flood damages. This measure includes the effects of anticipated changes such as residential development and business activity as well as expected physical changes that would effect the extent of flooding for various frequencies of flooding. Calculation of average annual equivalent damage requires assumption of a discount rate.

Backwater: The resulting high water surface in a given stream due to a downstream obstruction or high stages in an intersecting stream.

Base Year: The first year in which a project is expected to become fully operational.

Benefit-Cost Ratio: The arithmetic proportion of estimated average annual benefits to average annual cost, insofar as the factors can be expressed in monetary terms. The relation of benefits to costs represents the degree of tangible economic justification of a project.

Benefits: Increases or gains in the value of goods and services which result from conditions with the project as compared with conditions without the project.

Channel: The area between riverbanks or streambanks that holds the normal flow of water.

Channelization: The process of increasing the capacity of a channel to carry more water.

Cleanup Costs: The costs in labor and materials of removing silt and debris from buildings and outside property.

Confidence Level: The probability that the true value of a parameter lies within a stated interval.

Constant-Dollar Values (Real Dollar Values): A series of dollar values such as gross national product, personal income, sales, or profits from which the effect of changes in the purchasing power of the dollar has been removed.

Contents: Property situated within a structure which is not part of the structure. In residences, this would include personal property within the structure not affixed to the structure. In commercial, industrial, public, and institutional property, this would include inventory, furnishing, moveable equipment and supplies.

Continuing Authorities: Continuing Authorities permit the Secretary of the Army and the Chief of Engineers to undertake investigations and construction of small projects without separate congressional authority.

Contour: A line drawn on a map to join points of equal elevation. A number of contours, therefore, depict on a flat map the relief of the land over the area covered.

Cross Section: The physical dimensions of a river or stream channel at a given location.

Cubic Feet Per Second (CFS): A unit expressing rates of flow. One cubic foot (.0283636 cubic meter) per second is equal to the discharge of a stream of a rectangular cross-section, one foot wide and one foot deep.

Current Dollars: The value or price in actual dollars of the time being discussed, not adjusted for inflation.

Degree of Protection: The degree of protection is the criterion used to express the flood damage prevention effectiveness of a project. Generally, it is the frequency level at which flood damages and/or other adverse effects, not eliminated by the project, are considered relatively minor.

Design Flood: This is a flood adopted for the design of individual flood control works. It provides technically feasible protection which normally is economically justified for a given magnitude of flooding, below which flood damages are negligible or non-existent.

Demand: The amounts of a commodity that buyers are willing to purchase at varying prices.

Dependent Variable: In regression analysis, a variable whose variation is explained by the other variables in the regression equation.

Depreciation: Depreciation: Is a loss of value caused by deterioration and/or obsolescence. Deterioration is reflected by wear and tear, decay or structural defects. Obsolescence occurs in two forms; functional and economic.

Depreciated Replacement Value: The cost of restoring flood-damaged property to its pre-flood condition or replacing with something of equivalent value, accounting for deterioration, functional obsolescence, or age.

Depth-damage Relationship: The expected amount of damage in dollars, or as a percentage of value, for each foot of flooding above or below the first floor of a structure, or for outside property, for each foot of flooding above the ground.

Detailed Project Report: Planning document for continuing authority investigations which serves both as a basis for construction approval by the Chief of Engineers and as a basis for preparation of contract plans and specifications.

Discharge: The rate of flow or volume of water flowing past a specific point within a given period of time, generally expressed in cubic feet per second (cfs).

Discount Rate: The interest rate used in plan formulation and evaluation for discounting future benefits and costs, or otherwise converting benefits and costs to a common time basis. It is based upon the estimated average cost of Federal borrowing as determined by the Secretary of the Treasury, taking into consideration the average yield during the 12 months preceding his determination, on interest-bearing marketable securities of the United States with remaining periods to maturity comparable to a 50-year period of investment. It is provided, however, that the rate cannot be raised or lowered more than one-quarter percent in any year.

Diversion: The taking of water from a stream or other body of water into a canal, pipe, or other conduit.

Drainage Basin: A part of the surface of the earth that is occupied by a drainage system, which consists of surface water together with all tributary surface streams and bodies of impounded surface water.

Dry Dam: A retarding structure for temporary storage to reduce peak flow. Permanent storage is not involved, and the detention reservoir can be used for other purposes (farming, grazing, recreation) between flood periods.

Economic Base Study: A study that evaluates the economic structure of a region to provide economic and demographic projections necessary for the appraisal of future water resource needs.

Economic Efficiency: Economic efficiency is the objective of producing goods and services at the lowest possible cost per unit of output for a given level of output.

Economic Rationality: Economic rationality is the assumption that activities having full knowledge of the flood hazard will attempt to maximize returns, and will not externalize their flood losses.

Economies of Scale: A condition that exists when a good or service can be supplied at a decreasing marginal cost.

Emergency Costs: Emergency costs include non-physical expenses resulting from a particular flood event. Emergency costs include expenses for monitoring and forecasting, flood fighting and disaster relief and increased costs of police, fire and military patrol, evacuation and reoccupation expenses, and the administrative costs of disaster relief. Emergency costs should be determined by specific survey or research and should not be estimated by applying arbitrary percentages to the physical damage estimates.

Employment Benefits: Benefits that result from direct use in construction or installation of a project of otherwise unemployed or underemployed labor. This benefit is applicable only to communities noted in the Fiscal Year Reference Handbook, which is published every year as an Engineering Circular.

Enhancement: An increase in a resource or its value resulting from a particular land use or utilization change due to measures that alleviate flooding.

Evacuation: Temporary or permanent movement of floodplain occupants and property from the floodplain.

Evacuation Costs: Temporary evacuation costs include the value of lost commuting time, additional expenses for transportation, lodging, food, and storage from evacuation. Permanent evacuation costs include purchase price of the land and buildings that are not salvaged, and the costs to move buildings and contents from the floodplain, and the costs to remove any improvements which may inhibit using the land as open space or for another type of development.

Exceedance Frequency: Percentage of values that exceed a specified magnitude (usually used in association with streamflows).

Externality: Synonymous with external effect. An uncompensated effect on parties other direct than users of the outputs of a plan. For example, increased damages to activities outside the protected area under the with-project condition or increases in property values adjacent to the floodplain.

Feasibility Report: Planning document for investigation by the Corps of potential water resources projects that are authorized in acts or resolutions of Congress. This report is used for decision-making purposes concerning the need for and desirability of undertaking specific projects and programs.

Flood: Water flowing or sitting above ground from the overflow of a body of water, rise in groundwater, or ponding of water outside of its usual confines.

Flood Characteristics: The physical characteristics of floods including stage frequency, duration, concentration, velocity, debris and silt load.

Flood Control: The physical detention or blocking of water.

Flood Crest: The maximum stage of elevation reached by the waters of a flood at a given location.

Flood Damage: Flood damage is broadly defined in this manual as being the total monetary value of all physical and non-physical losses due to flooding and the threat of flooding.

Flood Frequency: The number of times per a specified period on the average that floods of a certain magnitude are exceeded.

Floodplain: The areas adjoining a river, stream, watercourse, ocean, lake, or other body of standing water that have been or may be covered by floodwater.

Floodplain Management: The combination of structural and nonstructural efforts which are designed to reduce long-term flood damages.

Flood Profile: A graph showing the relationship of water surface elevation to location, the latter generally expressed as distance above mouth for a stream of water flowing in an open channel. It is generally drawn to show surface elevation for crest of a specific flood, but may be prepared for conditions at a given time or stage.

Floodproofing: The raising of a structure, blocking of an entry, or the reduction of hydrostatic pressure to relieve flood damage.

Flood Stage: The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.

Floodwall: A concrete barrier to keep flood water out of an area.

Flood Warning: Measures taken to detect approaching floods and warning floodplain occupants to take preparations.

Floodway: Part of natural storage area of a body of water that receives relatively high velocity flows. Floodway development is strictly prohibited for participants of the National Flood Insurance Program because of the velocities and the effect that structures can have on nearby flood stages.

Freeboard: The vertical distance between a design maximum water level and the top of structure. For example a levee designed to hold back a .02 percent flood may be built at 350 feet above mean sea level at a given location, while the estimation elevation of the .02 is only 347 feet.

Frequency (in statistics): The number of occurrences of a particular variable within a given sample or population.

Gaging Station: A particular site on stream, canal, lake, or reservoir where systematic observations of gage height or discharge are obtained. Gaging stations are also used to continuously measure the amount of rainfall

Groundwater: Water in the ground in the zone of saturation, from which wells, springs, and aquifers are supplied but can also raise enough to damage foundations and lower elevations of buildings.

Hydrograph: A graph showing stage, flow velocity, or other property of water with respect to time.

Hydrology: The science dealing with water on the land, including its occurrence, circulation, physical properties, and geographical distribution.

Hydraulics: The science dealing with the movement of water. This manual is concerned with fluvial hydraulics, the movement of water through river and stream channels.

Independent Variables: A variable whose variance is determined outside of the regression equation and is believed to significantly affect the variance of the dependent variable.

Intangible Losses: Items of loss or damage for which a market price is not available. These include such items as loss of life, creation of health hazards, inconvenience, and loss of aesthetic values.

Income Loss: The loss of net profits to business due to flood-induced closings. They usually result from a disruption of normal activities and are to be derived from specific independent economic data for the interests and properties affected. Prevention of income loss can be counted as a National Economic Development benefit only to the extent that such losses cannot be compensated for by postponement of an activity or transfer of the activity to other establishments.

Intensification Benefit: Benefit which arises because a project induces an activity to modify its operation on the floodplain, making it possible for the occupant to increase his net income over and above the reduction in flood damages.

Inundation Reduction Benefit: The flood control benefit from the alleviation of physical damages and other economic costs to floodplain occupants, assuming the same level of activity with or without a project.

Justified: A project is considered justified when the benefit-cost ratio is equal to or greater than one.

Land Use Analysis: a description as to how land is and might be utilized within a particular area. Land use analysis includes inventory of existing land uses, land suitability to various uses, and the allocation of anticipated activities to specific areas. In flood mitigation planning estimated changes in land use are based upon affected area requirements and the ability of the floodplain to better meet these requirements given various levels of protection.

Levee: An earth embankment, designed to hold out water.

Location Benefits: Increases in the aggregate net income of an affected area that results from new location of an activity into the newly protected floodplain.

Marginal Utility or Marginal Benefit: The extra units of economic output gained from an extra unit of input. A plant which operates at optimum capacity will always have marginal utility equal to marginal cost.

Mean Sea Level (M.S.L.): The average level of the sea, as calculated from a large number of observations taken at equal intervals of time. It is a standard level from which elevations are calculated.

Multi-Objective Planning: Planning to achieve more than one objective such as national economic development, regional economic development, and environmental quality.

Multiple-Purpose Projects: Projects which serve more than one purpose. Reservoir projects often are multiple-purpose (i.e., flood control, water supply, recreation, etc).

Net Benefits: The difference between average annual benefits obtainable through operation of a project and average annual cost of the project.

Net Income: Gross income minus the total cost of producing goods or service. Calculated for a specific accounting period.

Nonphysical Losses: National economic costs of flooding or threat of flooding, over-and-above direct physical damage. Nonphysical losses include: emergency costs, temporary relocation, net income losses resulting from the temporary shut down of a business activity, suppressed land market values, and the modified use of floodplain property.

Non-recurring Flood Damages: Those items of loss which, once experienced, are not likely to recur for various reasons. Damage to property is non-recurring if it is unlikely to be repaired or replaced after being damaged. A loss is non-recurring if flooding occurs at too short an interval to allow time for replacement or repair. These losses cannot be included in estimates of probable future damages for project evaluation.

OBERS: Economic and demographic projections published by the Office of Business Economics of the Commerce Department. These projections used to be done jointly with the Economic Research Service of the Agriculture Department. Projections are made for each state and Standard Metropolitan Statistical Area.

One-Percent Flood (also known as the one hundred year flood and intermediate regional flood): A flood with a peak flow magnitude that has a one percent chance of being equalled or exceeded in any year. It is based on statistical analyses of streamflow records available for the watershed and analyses of rainfall and runoff characteristics in the general region of the watershed. The one-percent flood would have an average frequency of occurrence of about once in 100 years. Similarly, the .2-percent flood has a peak flow magnitude with a .2 percent chance of being equalled or exceeded in any given year.

Open Space: Areas virtually free of buildings and traffic ways. Open space includes parks, forest, meadows, wetlands, and water bodies.

Peak Flow: The maximum instantaneous discharge of a flood at a given location. It usually occurs at or near the time of the flood crest, i.e.,the maximum stage or elevation reached by the flood flow.

Period of Analysis: The period of analysis is that time horizon over which needs shall be assessed and is the basis for the NED benefit-cost analysis. The period of analysis is usually 100 years for major reservoirs, mainline levees, major long-term urban protection and hurricane protection plans, and 50 years for most other flood control measures.

Physical Damage: The complete or partial destruction to buildings or parts of buildings; contents, including furnishings inventory, equipment, raw materials; damage to roads, sewers, bridges, power lines and other infrastructure. Physical damages are evaluated separately for residences, commercial, industrial and public properties, utilities, vehicles, and roads. Physical damage is often defined to include the direct expenses and value of time spent for cleanup.

Plan Formulation: The process of selecting the most satisfactory plan of improvement from a group of alternative possibilities after consideration of all factors, tangible and intangible.

Post-authorization Studies: Planning and design that is accomplished after the project is authorized.

Pre-authorization Studies: Studies made prior to, and leading to authorization of a project.

Preconstruction Planning: That planning work on an authorized project necessary to advance the project to the stage where the first major construction contract may be advertised after construction funds are appropriated.

__**Principles and Guidelines**__: Short for __Principles and Guidelines for Water and Related Land Resources Implementation Studies (P & G)__. Federal administrative guidelines for water resources planning. The __P & G__ are intended to ensure proper and consistent planning by Federal agencies in the formulation and evaluation of water and related land resources plans. Probable Maximum Flood: The flood that can be expected from the most severe combination of meteorological and hydrologic conditions reasonably possible in the region.

Profile: The graph of a functional relationship showing the elevation of a stream or river over a particular reach for a given frequency of event.

Project Life: The period during which a project provides protection to the level it was designed. The project life is usually the same time period as the period of analysis.

Public: A category of general property including civic centers, courthouses, schools, institutional property, utilities, transportation, military bases, park facilities and others owned by public or quasi-public jurisdictions.

Reconnaissance Report: Initial planning document for Continuing Authorities and feasibility studies to determine whether further investigation is warranted. In the preparation of this report, principal emphasis is on specification of a broad range of problems and opportunities related to the water resource management in the study area. At least one solution for the principal problem under study should be identified which appears likely to be feasible if more detailed studies are to be done.

Regression Analysis: A tool of econometric analysis, that can be used to define and test the effect on one dependent variable by other variables that are believed to influence its movement.

Reliability: The probability that the system will perform satisfactorily for at least a given period of time when used under stated conditions.

Residential: A category of general property. This category includes single family and multi-family residences, owned by the residents individually or cooperatively, by corporations, by government agencies or landlords.

Residual Flood Damages: Flood damages which occur even with a floodplain management plan.

Residual Value: The economic value of property remaining after a flood.

Risk: As used in cost-effectiveness analysis and operations research, a situation is characterized as risk if it is possible to describe all possible outcomes and to assign objective numerical probabilities to each.

Sampling: The process of determining characteristics of a population by collecting and analyzing data from a representative segment of the population.

Sensitivity Analysis: The calculation of the rate of change of the objective function with respect to a particular parameter. In evaluation of flood damage reduction projects, it is an analysis of the components of a plan based upon alternative assumptions and/or projections to determine if a change in a measure would appreciably affect plan choice, design or schedule. In other words, it is the illustration of how the benefit-cost ratio and net benefits would change under various assumptions.

Separable Justification: When an element in a project can be physically independent and has positive net economic benefits.

Stage: In hydrology, the height of the water surface above or below mean sea level or above or below an arbitrary gage height.

Standard Deviation: A measure of dispersion between actual and fitted values in the regression equation: the square root of the variance.

Standard Industrial Classification (SIC): The classification of establishments, published by the Office of Management and Budget, by major type of business activity in which they are engaged. Codes are published by 2-digit, 3-digit, 4-digit, and 5-digit detail.

Standard Metropolitan Statistical Areas (SMSA): A county or group of counties containing at least one city of 50,000 inhabitants or contiguous cities with a combined population of 50,000 or more. In addition to the county containing such city or cities, contiguous counties are included in the SMSA if they are metropolitan in character and are integrated socially and economically with the attributes of the outlying county as a place of work or residence for a concentration of nonagricultural workers. At least 75 percent of the labor force in a county must be nonagricultural and, usually, the county must have 50 percent or more of its population living in contiguous minor civil divisions with a density of at least 150 persons per square mile.

Standard Project Flood (SPF): The flood that may be expected from the most severe combination of meteorological and hydrological conditions that is considered reasonably characteristic of the geographical area in which the drainage basin is located, excluding extremely rare combinations.

Supply: The amount of a commodity that producers are willing and able to offer at varying prices.

Susceptibility: Susceptibility is the relationship between total value of a type of activity in a floodplain and the flood damages sustained by that activity. The relationship is a function of the characteristics of the flooding itself (depth, velocity, duration, etc.) the objects flooded (dwelling, materials, etc.), and their location.

Temporary Relocation: the transitory departure of residents from their permanent homes. Temporary relocation costs include expenses for shelter, food, and transportation, over-and-above the normal costs.

Threshold Level: For a given activity and year, the protection level at which the activity is indifferent to locating on or off the floodplain. The activity is indifferent when net incomes, on and off the floodplain, are equal. Threshold levels are crucial to location benefit measurement and to land use analysis.

Topography: A detailed description or representation of features of an area, both natural and artificial, based on a survey of the land surface.
Uncertainty: A situation is uncertain if there is no objective basis for assigning numerical probability weights to the different possible outcomes, or there is no way to describe the possible outcomes.

Unit Hydrograph: A graph showing flow values against time at a given location, usually measured in cubic feet per second. The area under the curve indicates one unit (e.g., one inch, one millimeter) of direct runoff from rainfall excess of some unit duration (e.g., one hour) and specific areal distribution (e.g., acres, square miles). Unit hydrographs can be developed from hydrographs recorded at gaging stations or developed synthetically for ungaged watersheds. Unit hydrographs provide a mechanism for changing different magnitudes of rainfall excess.

Urban Area: Development occupying a continuous area, consisting of residential, business, and public uses.

Velocity: The speed at which water travels, usually given in cubic feet per second.

Willingness-to-Pay: The net gain that would accrue to a consumer, measured in the monetary value of what would be given up to acquire a good or a service.

With-Project Condition: The condition of having a specific floodplain management plan in effect.

Without-Project Condition: The condition of not having a specific floodplain management project in effect as a result of the study. It is described in terms of what is most likely to occur within an area under evaluation without the specific action, regardless of sponsorship. The enforceable provisions of zoning and the Flood Insurance Act would be recognized under this condition.

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